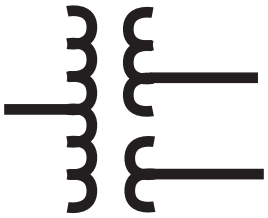
T-PRO

Transformer Protection Relay

Model 4000



User Manual

Version 1.2 Rev 1

Preface

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Using This Guide

This User Manual describes the installation and operation of the T-PRO transformer protection relay. It is intended to support the first time user and clarify the details of the equipment.

The manual uses a number of conventions to denote special information:

Example	Describes
Start>Settings>Control Panel	Choose the Control Panel submenu in the Settings submenu on the Start menu.
Right-click	Click the right mouse button.
Recordings	Menu items and tabs are shown in italics.
Service	User input or keystrokes are shown in bold.
Text boxes similar to this one	Relate important notes and information.
..	Indicates more screens.
▶	Indicates further drop-down menu, click to display list.
	Indicates a warning.

Acronyms

ASG - Active Setting Group

CID - file extension (.CID) for Configured IED Description
CT - Current Transformer

DCE - Data Communication Equipment
DIB - Digital Input Board
DIGIO - Digital Input/Output Board
DSP - Digital signal processor
DTE - Data Terminal Equipment

GFPCB - Graphics Front Panel Comm Board
GFPDB - Graphics Front Panel Display Board
GPS - Global Positioning System

HMI - Human Machine Interface

ICD - file extension (.ICD) for IED Capability Description
IEC - International Electrotechnical Commission
IED - Intelligent Electronic Device
IP - Internet Protocol (IP) address
IRIG-B - Inter-range instrumentation group time codes

LED - Light-emitting Diode
LHS - Left Hand Side
LOCB - L-PRO Output Contact Board
LOCBH - L-PRO Output Contact Board - HCFI

MPB - Main Processor Board
MPC - Micro Processor

PLC - Programmable Logic Controller

RAIB -Relay AC Analog Input Board
RASB -Relay AC Analog Sensor Boards
RHS - Right Hand Side
ROCOD ?Rate of Change of Differential
RPCB - Rear Panel Comm Board
RTOS - Real Time Operating System
RTU - Remote Terminal Unit

SCADA - Supervisory Control And Data Acquisition
SG - Setting Group

TUI - Terminal User Interface

UI - User Interface

VI - Virtual Input

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PC System Requirements and Software Installation

Hardware

The minimum hardware requirements are:

- 1 GHz processor
- 2 GB RAM
- 20 GB available hard disk space
- USB port
- Serial communication port

Operating System

The following software must be installed and functional prior to installing the applications:

- Microsoft Windows XP Professional Service Pack 3 or
- Microsoft Windows 7 Professional Service Pack 1

Software Installation

The CD-ROM contains software and the User Manual for the T-PRO Transformer Protection Relay.

Software is installed directly from the CD-ROM to a Windows PC. Alternatively, create installation diskettes to install software on computers without a CD-ROM drive.

The CD-ROM contains the following:

- T-PRO *Offliner* Settings: *Offliner* settings program for the T-PRO relay
- T-PRO Firmware: Firmware and installation instructions.
- T-PRO User Manual: T-PRO manual in PDF format
- Relay Control Panel: software
- Relay Control Panel User Manual: manual in PDF format
- USB Driver

To Install Software on your Computer

Insert the CD-ROM in your drive. The CD-ROM should open automatically. If the CD-ROM does not open automatically, go to Windows Explorer and find the CD-ROM (usually on D drive). Open the ERLPhase.exe file to launch the CD-ROM.

To install the software on your computer, click the desired item on the screen. The installation program launches automatically. Installation may take a few minutes to start.

To view the T-PRO User Manual the user must have Adobe Acrobat on your computer. If a copy is needed, download a copy by clicking on Download Adobe Acrobat.

Anti-virus/Anti-spyware Software

If an anti-virus/anti-spyware software on your local system identifies any of the ERLPhase applications as a “potential threat”, it will be necessary to configure your anti-virus/anti-software to classify it as “safe” for its proper operation. Please consult the appropriate anti-virus/anti-spyware software documentation to determine the relevant procedure.

Version Compatibility

This chart indicates the versions of Offliner Settings, RecordBase View and the User Manual which are compatible with different versions of T-PRO firmware.

RecordBase View and Offliner Settings are backward compatible with all earlier versions of records and setting files. You can use RecordBase View to view records produced by any version of T-PRO firmware and Offliner Settings can create and edit older setting file versions.

Minor releases (designated with a letter suffix - e.g. v3.1a) maintain the same compatibility as their base version. For example. T-PRO firmware v3.1c and *Offliner* Settings v3.1a are compatible.

T-PRO Firmware/Software Compatibility Guide

T-PRO Firmware	RCP Version	Setting Version	Compatible Offliner Settings	Compatible RecordBase View	ICD File Version
v1.2	v2.5 or greater	403	v1.3 or greater	v3.0 or greater	3.0
v1.1	v2.4 or greater	402	v1.2 or greater	v3.0 or greater	2.0
v1.0a	v2.0 or greater	401	v1.0 or greater	v3.0 or greater	2.0
v1.0	v2.0 or greater	401	v1.0 or greater	v3.0 or greater	2.0

Please contact ERLPhase Customer Service for complete Revision History.

1 Overview

1.1 Introduction

The T-PRO 4000 is a numerical relay providing protection, monitoring, logging and recording for a Transformer. A patented Transformer Overload Early Warning System (TOEWS) algorithm, based on IEEE C57.91 Loss of Life design standards, determines safe transformer loading conditions and issues early warning on over loading and aging conditions.

The Relay Control Panel (RCP) is the Windows graphical user interface software tool provided with all 4000 series and new generation ERL relays to communicate, retrieve and manage records, fault logs, event logs, manage settings (identification, protection, SCADA etc.) and display real time metering values, view, analyze.

The primary protection is percent restrained current differential. The restraint is user-definable. 2nd and 5th harmonic restraint are provided as well as a high current unrestrained setting.

To provide a complete package of protection and control, T-PRO provides other functions such as:

- Low Impedance Restricted Earth Fault (87N) / High Impedance Restricted Earth Fault (50N)
- Digital control of current inputs
- Temperature monitoring
- TOEWS for asset monitoring loss of life
- Adaptive Pickup Overcurrent, Thermal Overload, Directional Overcurrent and Neutral Overcurrent
- Breaker Fail function for each current input
- Overexcitation, Definite Time and Inverse Time
- Fixed Level or Rate of Change of Overfrequency and Underfrequency
- Phase Undervoltage, Phase Overvoltage and Neutral Overvoltage
- Total Harmonic Distortion (THD)
- Through Fault Monitoring
- ProLogic control statements to address special protection and control needs
- 96 Sample per cycle recording of all analog channels and events
- Trend Recording
- 8 Setting Groups (SG) with setting group logic

Relay Control Panel (RCP) is the Windows graphical user interface software tool provided with 4000 series and higher (new generation) ERL relays to communicate, retrieve and manage records, event logs, fault logs, manage settings

(identification, protection, SCADA etc.,), display real time metering values, view, analyze, and export records in COMTRADE format.

In addition to the protection functions the relay provides fault recording (96 samples/cycle) to facilitate analysis of the power system after a disturbance has taken place. The triggers for fault recording are established by programming the output matrix and allowing any internal relay function or any external input to initiate a recording. The T-PRO can also create continuous, slow-speed trend recording of the transformer and its characteristics with an adjustable sample period. Trend records can be stored for 30 to 600 days depending on the sample period.

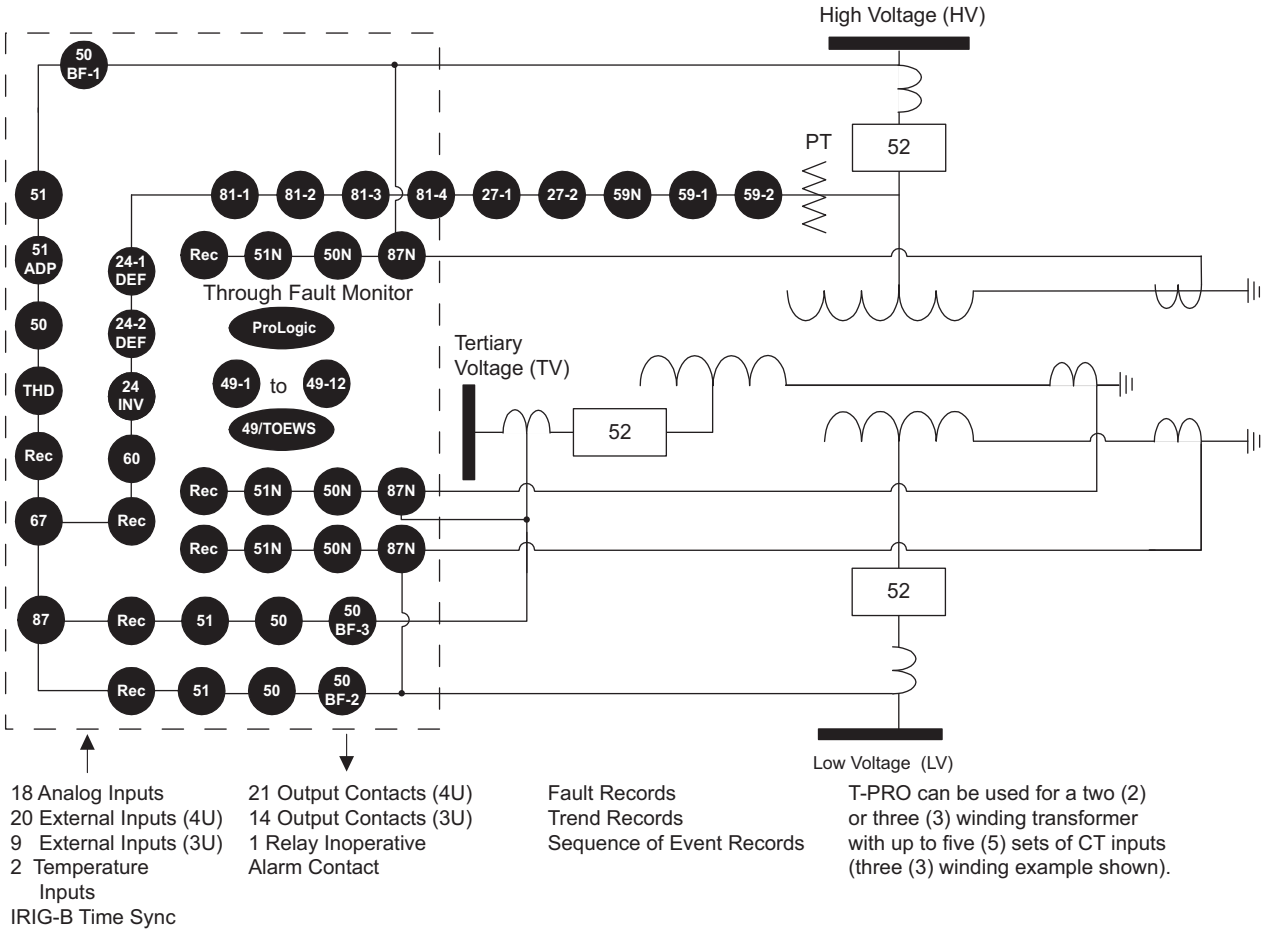
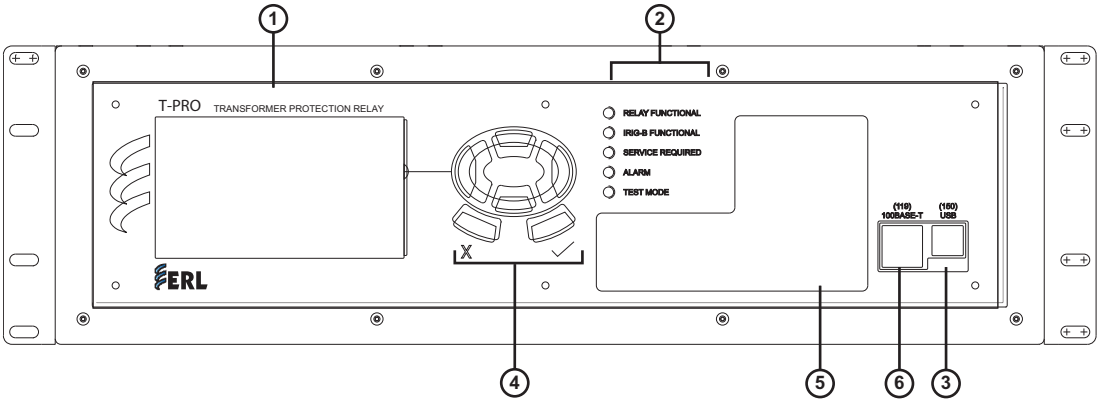


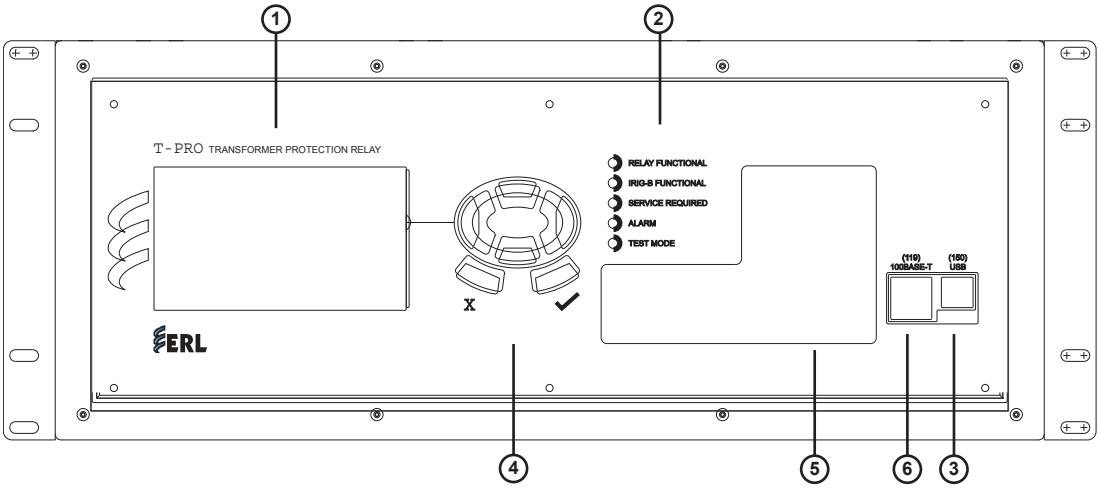
Figure 1.1: T-PRO Function Line Diagram

1.2 Front View



1. Front display of time, alarms, relay target, metering and settings
2. LEDs indicating status of relay
3. USB Port 150 for maintenance interface, setting changes and calibration
4. Push buttons to manipulate information on display and to clear targets
5. 11 programmable target LED's
6. Ethernet Port 119

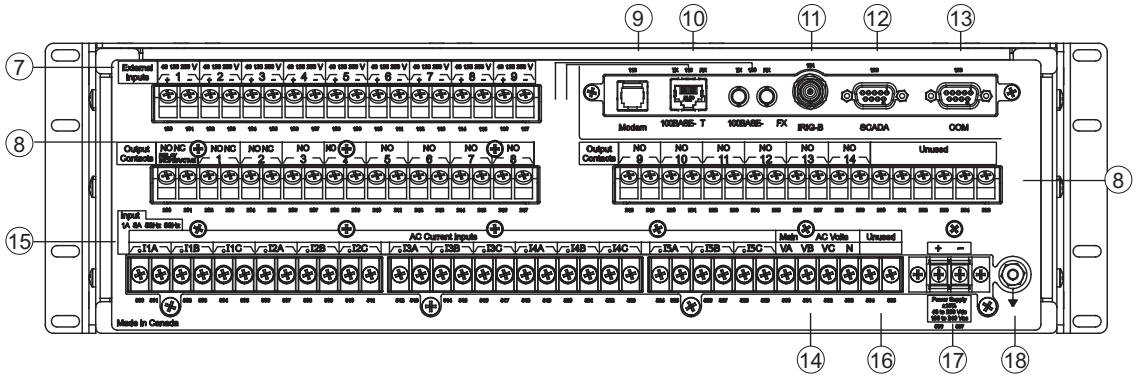
Figure 1.2: T-PRO Front View (3U)



1. Front display of time, alarms, relay target, metering and settings
2. LEDs indicating status of relay
3. USB Port 150 for maintenance interface, setting changes and calibration
4. Push buttons to manipulate information on display and to clear targets
5. 11 programmable target LED's
6. Ethernet Port 119

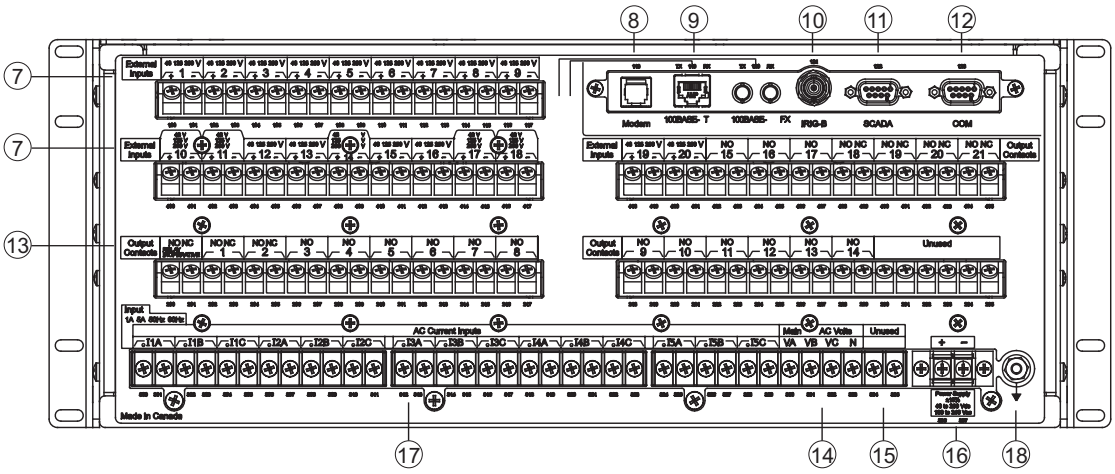
Figure 1.3: T-PRO Front View (4U)

1.3 Back View



7. Ports 100-117: 9 External Programmable Inputs
8. Ports 200-201: Relay inoperative contact
   Ports 202-229: 14 programmable output contacts
   Ports 230-235: Unused
9. Port 118: Internal modem
10. Port 119-120: 100BASE-T or 100BASE-FX Ethernet Ports
11. Port 121: External clock, IRIG-B modulated or unmodulated
12. Port 122: SCADA
13. Port 123: Direct/Modem RS-232 Port
14. Ports 330-333: AC voltage inputs
15. Ports 300-329: AC current inputs
16. Ports 334, 335: Unused
17. Ports 336-337: Power supply
18. Port with GND symbol: Chassis Ground

Figure 1.4: T-PRO Back View (3U)



7. Ports 100-117, 400-421: 20 External Programmable Inputs
8. Port 118: Internal modem
9. Port 119-120: 100BASE-T or 100BASE-FX Ethernet Ports
10. Port 121: External clock, IRIG-B modulated or unmodulated
11. Port 122: SCADA
12. Port 123: Direct/Modem RS-232 Port
13. Port 200-229, 422-435: 21 programmable output contacts
14. Port 330-333: AC voltage inputs
15. Port 334-335: unused
16. Port 336-337: Power supply
17. Port 300-329: AC current inputs
18. Port with GND symbol: Case ground

Figure 1.5: T-PRO Back View (4U)

AC Current and Voltage Inputs

T-PRO is provided with terminal blocks for up to 15 ac currents and 3 phase-to-neutral voltages.

Each of the current input circuits has polarity (·) marks.

A complete schematic of current and voltage circuits is shown, for details see "AC Schematic Drawing" in Appendix I and "DC Schematic Drawing" in Appendix J.

External Inputs

The T-PRO relay has:

- 9 programmable external inputs in the standard 3U model
- 20 external inputs in the optional 4U model

External dc voltage of either 48 Vdc, 110/125 Vdc or 220/250 Vdc nominal are possible depending on the range requested. Selection of specific voltage is factory selectable.

To guarantee security from spurious voltage pulses, the T-PRO has an external input pickup filter setting. This setting is made in Relay Control Panel under *Utilities > External Inputs*. The setting is an integer number representing the number of samples in a packet of 12 that must be recognized by the DSP as high before an External Input status is changed from low to high. See specifi-

cations for External Input Pickup Filter in “IED Specifications” in Appendix A.

Temperature Inputs

The T-PRO 4000 is capable of receiving 2 sets of isolated 4-20 mA current loops for ambient and top oil temperatures. This optional feature has to be specified while ordering.

Output Relay Contacts

The T-PRO Relay has:

- 14 configurable output relay contacts in the standard 3U model
- 21 configurable outputs in the optional 4U model.

Each contact is programmable and has breaker tripping capability. All output contacts are isolated from each other. The output contacts are closed for a minimum of 120 ms after the initiating element drops out.

Relay Inoperative Alarm Output

If the relay is in self check mode or becomes inoperative, then the Relay Inoperative Alarm output contact closes and all tripping functions are blocked.

1.4 Model Options/Ordering

T-PRO is available as a horizontal mount, for details see “Mechanical Drawings” in Appendix G.

T-PRO is available with an optional internal modem card.

The two rear Ethernet ports can be ordered as one copper-one optical port or both optical ports or both copper ports. T-PRO is available with an optional two temperature inputs (Ambient & Top-Oil).

These ports on the rear panel are available as either 100BASE-T (RJ-45) or 100BASE-FX (optical ST).

The CT inputs are 1 A nominal or 5 A nominal.

The external inputs are 48 Vdc, 110/125 Vdc or 220/250 Vdc.

The system base frequency is either 50 Hz or 60 Hz.

The T-PRO 4000 is available in a standard 3U rack model or as 4U model with an optional I/O board as described above.

All of the above options must be specified at the time of ordering.

2 Setup and Communications

2.1 Introduction

This chapter discusses setting up and communicating with the T-PRO relay including the following:

- Power supply
- Inter-Range Instrumentation Group time codes (IRIG-B) time input
- Communicating with the relay using a network link
- Communication with the relay using a direct serial link
- Using a Modem link (internal, external)
- Using ERLPhase Relay Control Panel to access the relay's user interface
- Using HyperTerminal to access the relay's Maintenance and Update menus
- Setting the Baud rate
- Accessing the relay's Supervisory Control Data Acquisition (SCADA) services

2.2 Power Supply

A wide range power supply is standard. The nominal operating range is 48 – 250 Vdc, 100 – 240 Vac, +/-10%, 50/60 Hz. To protect against a possible short circuit in the supply, the power supply should be protected with an inline fuse or circuit breaker with a 5 A rating.

Ensure that the chassis is grounded for proper operation and safety.

There are no power switches on the relay. When the power supply is connected, the relay starts its initialization process. For details see "Start-up Sequence" on page 3-1.

Case Grounding

You must ground the relay to the station ground using the case-grounding terminal at the back of the relay, for details see Figure 1.4: T-PRO Back View (3U) on page 1-4.

WARNING!

Ground the relay to station ground using the case-grounding terminal at the back of the relay, for details see Figure 1.4: T-PRO Back View (3U) on page 1-4

2.3 IRIG-B Time Input

The T-PRO is equipped to handle IRIG-B modulated or unmodulated signals and detects either automatically. The IRIG-B time signal is connected to the Port 121 (BNC connector) on the back of the relay. When the IRIG-B signal is healthy and connected to the relay, the IRIG-B Functional LED on the front of the relay will illuminate and the relay's internal clock will be synchronized to this signal.

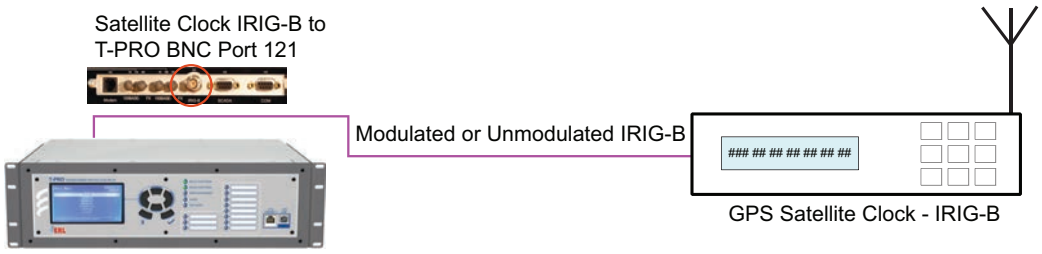


Figure 2.1: T-PRO IRIG-B Clock Connection

In order to set the time in the T-PRO relay, access the setting in Relay Control Panel under the *Utilities* > *Time* tab, which is shown in Figure 2.2: on page 2-2. The "Use IEEE 1344" setting allows the T-PRO to utilize the year extension if it is received in the IRIG-B signal. If the available IRIG-B signal has no year extension, this setting should be disabled.

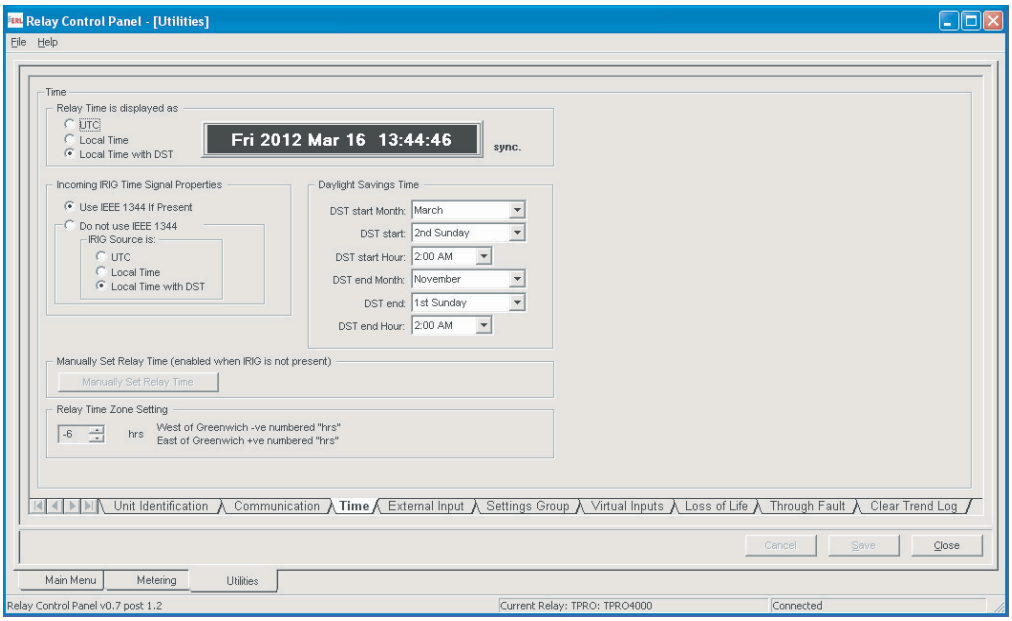


Figure 2.2: Relay Control Panel Date/Time Settings

2.4 Communicating with the T-PRO Relay

Connect to the relay to access its user interface and SCADA services by:

- Front USB 2.0 Service port (Port 150)
- 1 front Ethernet and 1 rear copper or optical Ethernet network links (Port 119)
- Additional optical Ethernet port (Port 120)
- Direct user interface and SCADA serial links (Ports 122 and 123)
- Internal Modem RJ-11 (Port 118)
- IRIG-B Time Synchronization (Port 121)

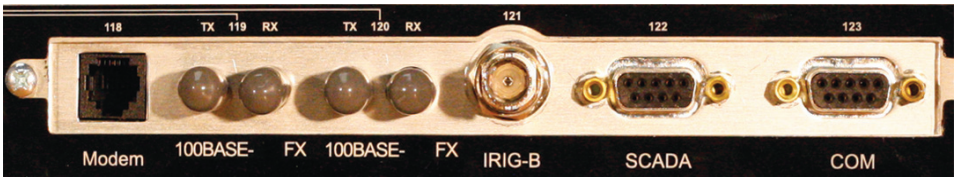


Figure 2.3: T-PRO Rear Ports

Aside from Maintenance and Update functions which will use a VT100 (e.g., Hyperterminal) connection, all other functions access the T-PRO user interfaces through ERLPhase Relay Control Panel software.

2.5 USB Link

The PC must be appropriately configured for USB Serial communication.

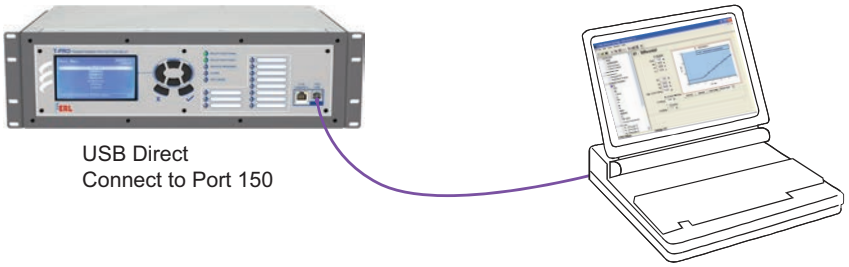


Figure 2.4: Direct USB Link

The T-PRO front USB Port 150 is also known as the Service Port. To create a USB link between the T-PRO and the computer, connect the computer USB port to the Port 150 on the T-PRO front panel using a standard USB peripheral cable.

The USB driver is available on the CD-ROM as well as in the Support Software downloads section on the

ERLPhase website: http://erlphase.com/support.php?ID=software.

See below under USB Driver a detail explanation on how to install the USB Driver. Ensure the relay port and computer port have the same baud rate and communication parameters.

The relays USB port appears as a serial port to the computer and is fixed at 8 data bits, no parity, 1 stop bit. The T-PRO Port 150 default baud rate is 115,200

When you connect to the T-PRO Service Port, Relay Control Panel will prompt for a Service Access Password. Enter the default password **service** in lowercase.

USB Driver Installation

To create an USB link between the relay and the computer, first the USB driver for the ERLPhase 4000 series device needs to be installed, as follows:

Unzip the file (can be obtained from ERL website):

ERLPhase_USB_driver.zip

In this case we assume you unzipped to the desktop.

In Windows XP or Windows 7

Power on the T-PRO and wait until the “Relay Functional” LED lights up; connect a USB port of the PC to Port 150 (USB front) of the T-PRO 4000.

In the window

"Welcome to the Found New Hardware Wizard"

"Can Windows connect to Windows Update to search for software?"

Check the option "No, not this time".

In the window

"This wizard helps you install software for:"

"ERLPhase 4000 Series Device"

"What do you want the wizard to do?"

Check the option "Install from a list or specific location (Advanced)".

In the window

"Please choose your search and installation options"

"Search for the best driver in these locations"

Uncheck the option "Search removable media (floppy, CD-ROM.)".

Check the option "Include this location in the search".

Browse for the following folder:

C:\WINDOWS\tiinst\TUSB3410

In the window

"Hardware Installation"

"The software you are installing for this hardware"

"ERLPhase 4000 Series Device"

"has not passed Windows Logo testing to verify its compatibility with Windows XP"

Hit *Continue Anyway*.

In the window

"Completing the Found New Hardware Wizard"

"The wizard has finished installing the software for"

"ERLPhase 4000 Series Device"

Hit *Finish*.

To verify the installation was successful, and to which comm port is the ERLPhase 4000 Series Device configured, do the following:

In Windows XP go to

Start > Control Panel->Performance and Maintenance->System >Hardware > Device Manager > Ports

or (if using Control Panel's Classic View)

Start > Control Panel > System > Hardware >Device Manager >Ports

In Windows 7 'small icons' view go to

Start>Control Panel>Device Manager>Ports

Look for the port number associated to this device

"ERLPhase 4000 Series Device"

Look for a COM#, where "#" can be 1, 2, 3, etc. Leave the default settings for this port.

It is recommended to restart the PC after the USB driver installation.

The default baud rate for the relay USB Port 150 is 115200, however to double check it login to the relay display and go to:

Main Menu > System > Relay Comm Setup

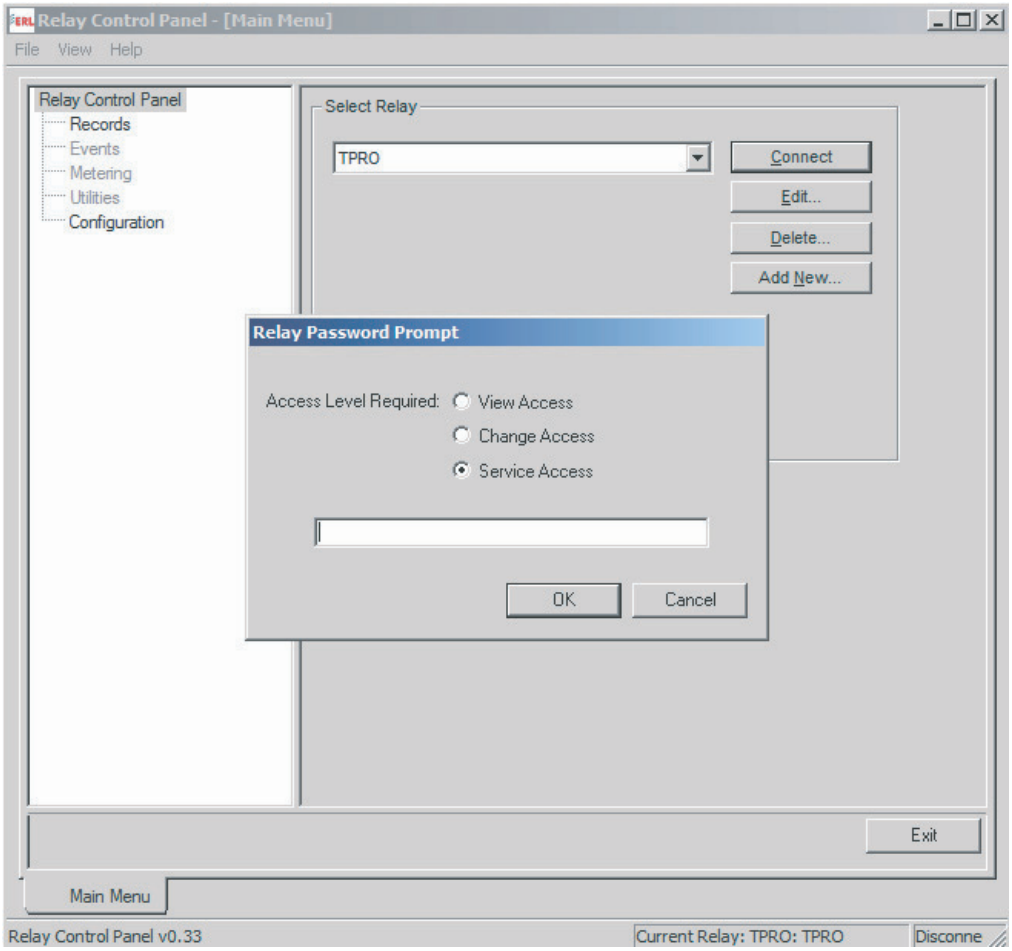


Figure 2.5: Logging into the Service Port 150 in Relay Control Panel

2.6 Network Link

Access the relay's user interface and DNP3 SCADA services simultaneously with the Ethernet TCP/IP (Internet Protocol) LAN link through the rear network ports Port 119 and Port 120. Ports 119 and 120 are either 100BASE-T copper interface with an RJ-45 connector or 100BASE-FX optical interface with an ST style connector. Each port is factory configurable as a copper or optical interface. The front Port 119 is 100BASE-T copper interface with an RJ-45 connector.

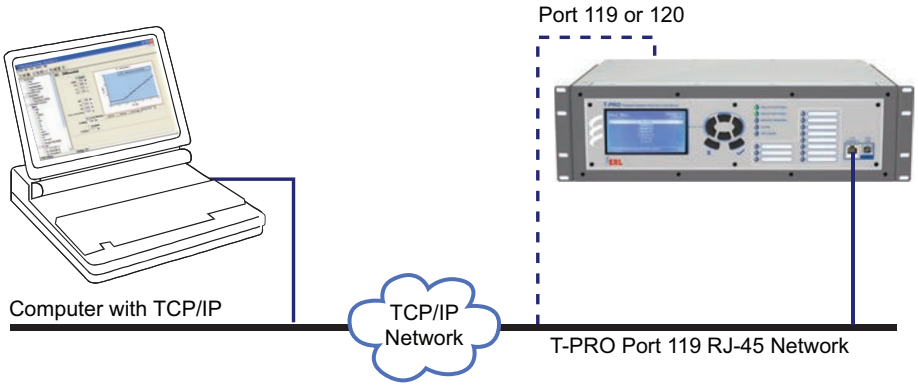


Figure 2.6: Network Link

DNP3 SCADA services can also be accessed over the LAN, for details see Table 2.4: Communication Port Details on page 2-20.

Connect to the Ethernet LAN using a CAT 5 cable with an RJ-45 connector or 100BASE-FX 1300 nm, multimode optical fiber with an ST style connector.

By default, the Port 119 is assigned with an IP address of 192.168.100.80. Port 120 is assigned with an IP address of 192.168.101.80. If this address is not suitable, it may be modified using the relay's Maintenance Menu. For details see "Using HyperTerminal to Access the Relay's Maintenance Menu" on page 2-13.

2.7 Direct Serial Link

To create a serial link between the relay and the computer, connect the computer's serial port and Port 123 on the relay's rear panel, provided the port is not configured for modem use. When connected, run Relay Control Panel to establish the communication link.

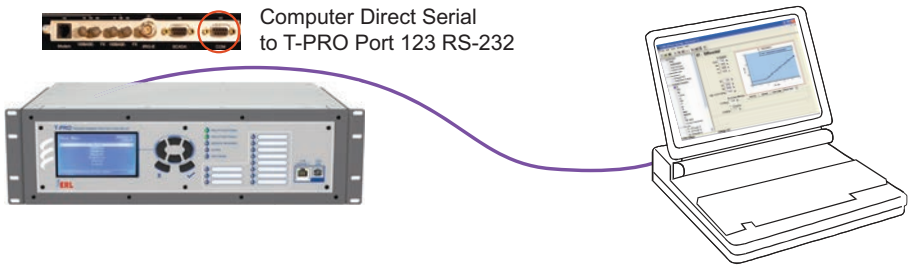


Figure 2.7: Direct Serial Link

The serial ports are configured as EIR RS-232 Data Communications Equipment (DCE) devices with female DB9 connectors. This allows them to be connected directly to a computer serial port with standard straight-through male-to female serial cable. For pin-out details see Table 2.4: Communication Port Details on page 2-20. Rear Port 122 is for SCADA and Port 123 can be used for direct serial access and external modem.

Ensure the relay port and the computer port have the same baud rate and communications parameters.

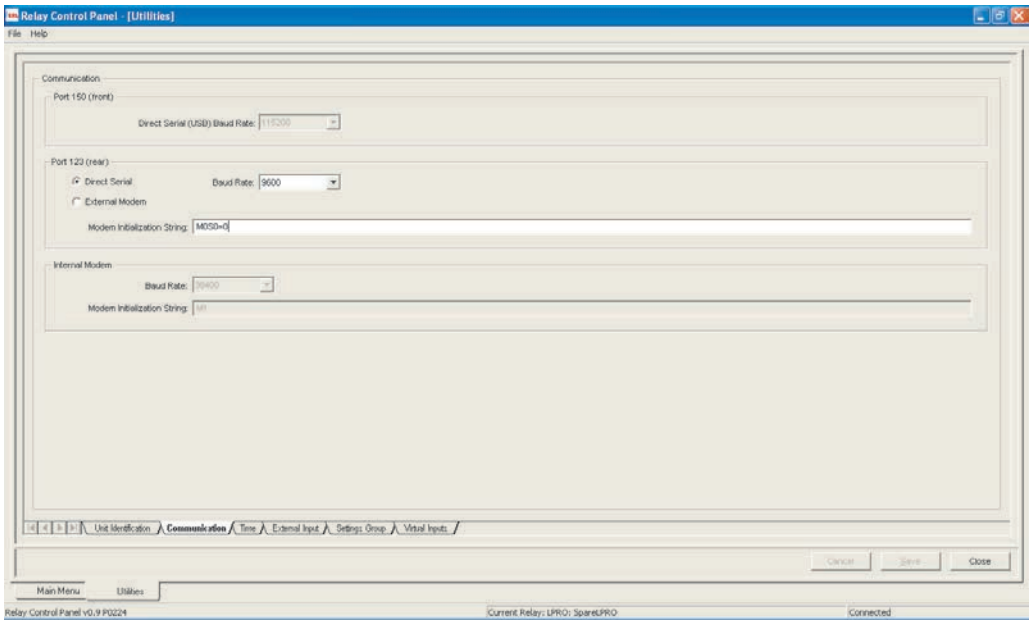


Figure 2.8: Port 123 Direct Serial Configuration in Relay Control Panel

2.8 Modem Link

External Modem

Access the T-PRO's user interface through a telephone link between the relay and the computer by using an external modem.

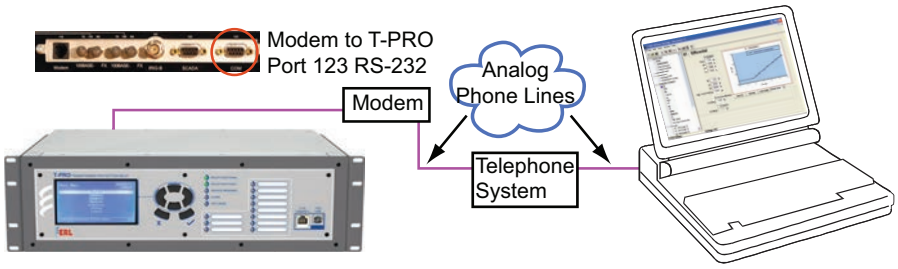


Figure 2.9: Modem External Link

Connect the serial port of the external modem to the Port 123 on the T-PRO rear panel. Both devices are configured as RS-232 DCE devices with female connectors, so the cable between the relay and the modem requires a crossover and a gender change. Alternatively, use the ERLPhase modem port adapter provided with the relay to make Port 123 appear the same as a computer's serial port. A standard modem-to-computer serial cable can then be used to connect the modem to the relay. For pin-out details see "Communication Port Details" on page 2-20.

Connect the modem to an analog telephone line or switch using a standard RJ-11 connector.

In Relay Control Panel, configure the relay's Port 123 to work with a modem. Go to *Utilities* > *Communication* and select *Port 123*. Set the *Baud Rate* as high as possible; most modems handle 57,600 bps. The *Modem Initialize String* setting allows the user to set the control codes sent to the modem at the start of each connection session. The external modem factory defaults initialization string is "M0S0=0".

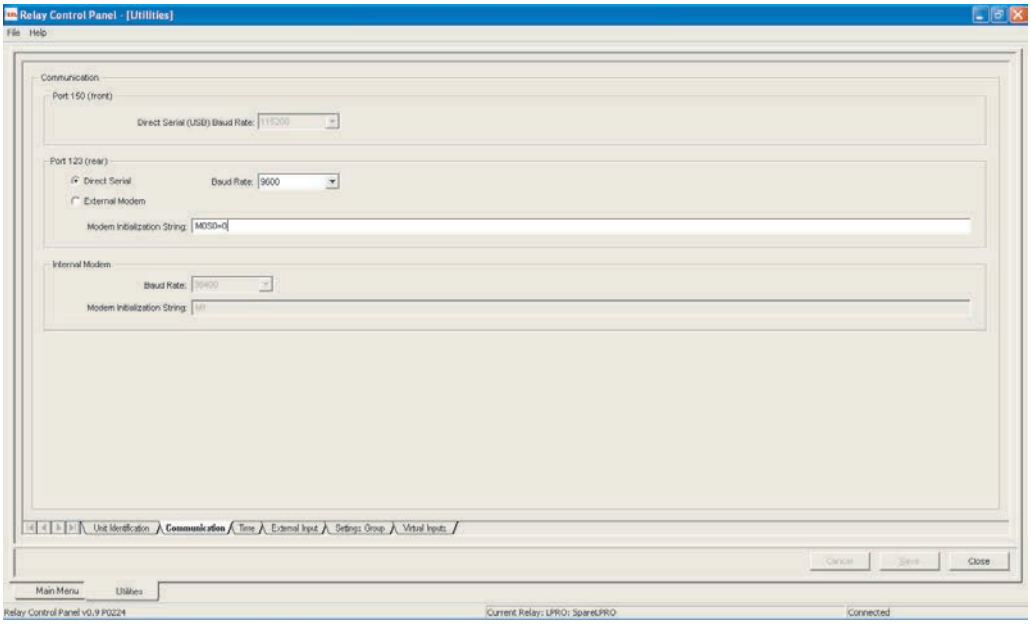


Figure 2.10: Port 123 Settings for External Modem Link in Relay Control Panel

Internal Modem

Access the T-PRO user interface through a telephone link between the relay and the computer using an optional internal modem. If the modem has been installed, Port 118 on the rear panel is labelled *Internal Modem* and the modem hardware is configured inside the relay.

Connect the relay's Port 118 to an analog telephone line or switch using a standard RJ-11 connector.

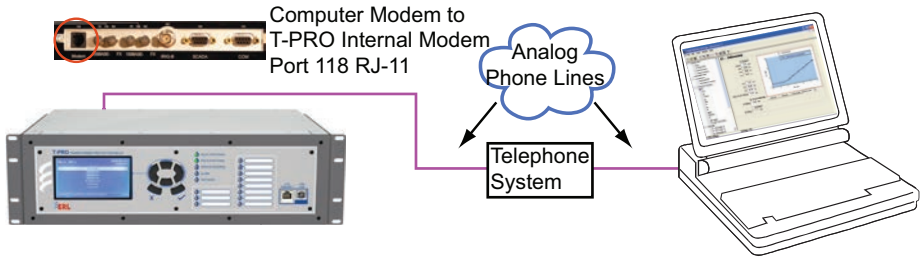


Figure 2.11: Internal Modem Link

The appropriate Port 118 settings are configured at the factory when the internal modem is installed. The factory default initialization string for and Internal modem is "M0S0=0".

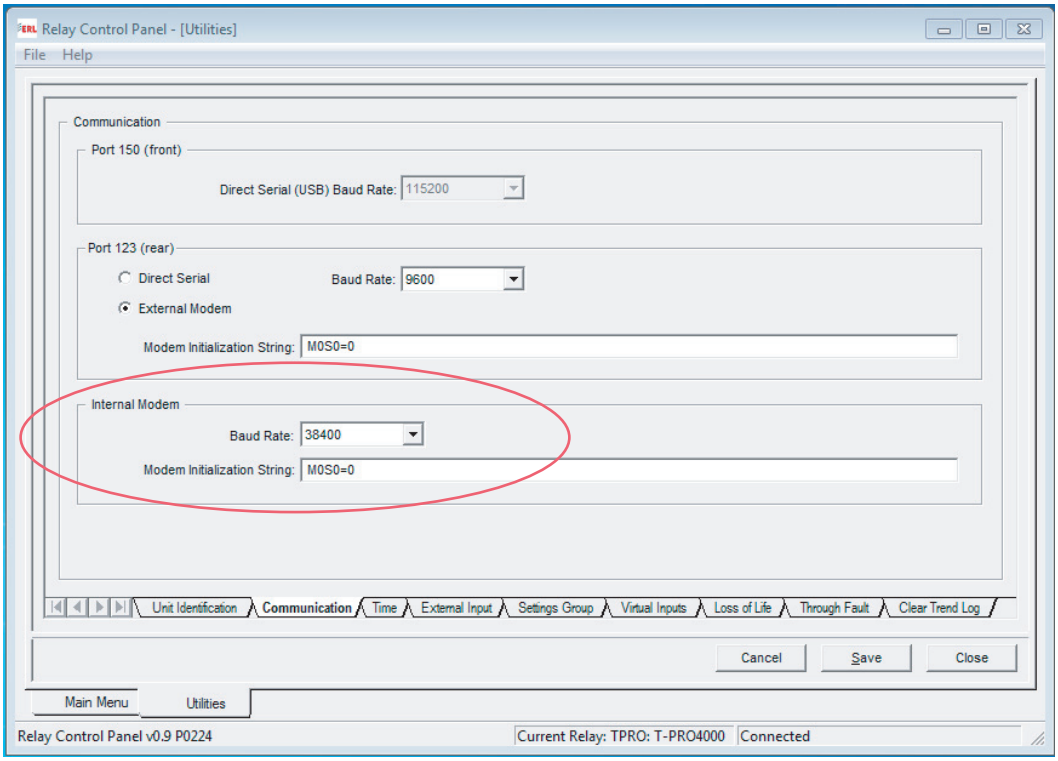


Figure 2.12: T-PRO Internal Modem Settings in Relay Control Panel (circled settings are available when Internal Modem is installed)

2.9 Using HyperTerminal to Access the Relay's Maintenance Menu

This section describes how to configure a standard Windows VT-100 terminal program on the computer for use with the T-PRO in order to access the T-PRO maintenance and update functions.

The computer must be connected to the relay via the front USB service port 150.

The relay is accessed using a standard VT-100 terminal style program on the computer, eliminating the need for specialized software. Any terminal program that fully supports VT-100 emulation and provides Z-modem file transfer services can be used. For example, the HyperTerminal program, which is included in Windows XP and is also available separately as HyperTerminal PE, is used here as an example.

Configure the terminal program as described in Table 2.1: on page 2-13 and link it to the appropriate serial port, modem or TCP/IP socket on the computer.

Table 2.1: Terminal Program Setup

Baud rate	Default fixed baud rate 115,200 N81 (no parity, 8 data bits, 1 stop bit).
Data bits	8
Parity	None
Stop bits	1
Flow control	Hardware or Software. Hardware flow control is recommended. The relay automatically supports both on all its serial ports.
Function, arrow and control keys	Terminal keys
Emulation	VT100
Font	Use a font that supports line drawing (e.g. Terminal or MS Line Draw). If the menu appears outlined in odd characters, the font selected is not supporting line drawing characters.

To configure HyperTerminal follow this instructions:

In Windows 7 open HyperTerminal PE; in Windows XP go to

Start > All Programs > Accessories > Communications > HyperTerminal

If "Default Telnet Program?" windows pops up,

Check "Don't ask me this question again"

Hit *No*.

First time use of HyperTerminal will ask for "Location Information".

Fill with appropriate information, e.g.:

"What country/region are you in now"

Choose "Canada"

"What area code (or city code) are you are in now?"

Enter "306"

"If you need to specify a carrier code, what is it?"

Enter "", i.e. leave blank

"If you dial a number to access an outside line, what is it?"

Enter "".

"The phone system at this location uses:"

Choose "Tone dialing".

Hit *OK*.

First time use of HyperTerminal will show "Phone and Modem Options".

Hit *Cancel*.

Hyperterminal will show initially "Connection Description".

Enter a name for the relay, e.g: "TPRO4000".

Hit *OK*.

In the window "Connect To"

"Connect using"

Choose "COM#", where "#" was obtained previously in Section 2.5 USB Link, after installing the USB driver.

Let's assume in this case it is COM3.

In the window "COM3 Properties" choose:

"115200"

"8"

"None"

"1"

"Hardware"

Hit *Apply* then hit *OK*

At this time the connection should already be established.

Hit *Enter* in the terminal window.

To initiate a connection with the relay use HyperTerminal's *Call* > *Connect* function.

When the connection is established, press *Enter* in the terminal window. At the login prompt, enter **maintenance** in lower case, which will bring up the menu shown in Figure 2.13: Maintenance Menu on page 2-15.

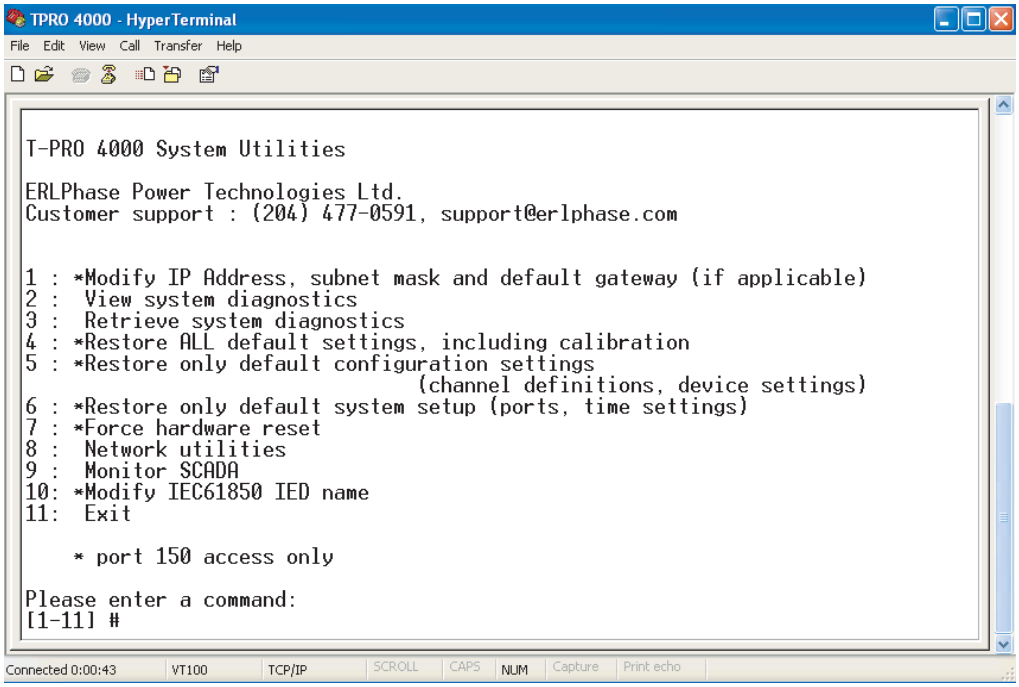

TPRO 4000 - HyperTerminal
File Edit View Call Transfer Help
T-PRO 4000 System Utilities
ERLPhase Power Technologies Ltd.
Customer support : (204) 477-0591, support@erlphase.com
1 : *Modify IP Address, subnet mask and default gateway (if applicable)
2 : View system diagnostics
3 : Retrieve system diagnostics
4 : *Restore ALL default settings, including calibration
5 : *Restore only default configuration settings
(channel definitions, device settings)
6 : *Restore only default system setup (ports, time settings)
7 : *Force hardware reset
8 : Network utilities
9 : Monitor SCADA
10: *Modify IEC61850 IED name
11: Exit
* port 150 access only
Please enter a command:
[1-11] #
Connected 0:00:43
VT100
TCP/IP
SCROLL
CAPS
NUM
Capture
Print echo

Figure 2.13: Maintenance Menu

Maintenance Menu Commands

Commands 1, 4, 5, 6, 7 and 10 are Port 150 access only.

Table 2.2: Maintenance Menu Commands

Modify IP address	Modifies the LAN IP addresses, network mask, default gateway and IEC61850 network port assignment.
View system diagnostic	Displays the internal status log.
Retrieve system diagnostics	Automatically packages up the internal status log plus setting and setup information and downloads it in compressed form to the computer. This file can then be sent to our customer support to help diagnose a problem.
Restore settings (commands 4, 5 and 6)	Use these commands to force the system back to default values, if a problem is suspected due to the unit's settings, calibration and/or setup parameters.
Force hardware reset	Manually initiates a hardware reset. Note that the communication link is immediately lost and cannot be reestablished until the unit completes its start-up.

Table 2.2: Maintenance Menu Commands	
Network utilities	Enters network utilities sub-menu, for details see Table 2.3: Network Utilities on page 2-16.
Monitor SCADA	Shows real time display of SCADA data.
Modify IEC61850 IED name	Modifies IED name of the IEC61850 device. This name has to match the name in the CID file and the name change via this command shall be coordinated with the new CID file download.

Table 2.3: Network Utilities	
View protocol statistics	View IP, TCP and UDP statistics.
View active socket states	View current states of active sockets.
View routing tables	View routing tables.
Ping	Check network connection to given point.
Exit network utilities	Exit network utilities menu and return to Maintenance Menu Commands.

2.10 Firmware Update

The relay has an “update” login that can be accessed by a connection through a VT100 terminal emulator (such as HyperTerminal). This login is available only from Port 150.

1. Use the terminal program to connect to USB service Port 150.
2. Select *Enter:* the terminal responds with a login prompt.
3. Login as **update** in lower case.
4. The firmware update is used to update the relay’s internal software with the latest maintenance or enhancement releases. Please see the T-PRO Firmware Update Procedure documentation that comes with the firmware update file and instructions.

Note: The mouse does not work in VT100 terminal mode.

2.11 Setting the Baud Rate

The baud rate is available on the LCD screen from the top level menu selecting *System* then *Relay Comm Setup*.

Direct Serial Link

For a direct serial connection, both the relay and the computer must be set to the same baud rate.

To change the baud rate of a relay serial port:

1. The user needs to log into the relay as **Change** (any port) or **Service** (USB port only) using RCP.
2. Then choose *Utilities>Communication* tab.

Modem Link

Unlike a direct serial link, the baud rates for a modem link do not have to be the same on the computer and on the relay. The modems automatically negotiate an optimal baud rate for their communication.

The baud rate set on the relay only affects the rate at which the relay communicates with the modem. Similarly, the baud rate set in HyperTerminal only affects the rate at which the computer communicates with its modem. Details on how to set these respective baud rates are described above, except that the user modifies the Port 123 baud rate on the relay and the properties of the modem in HyperTerminal.

2.12 Accessing the Relay's SCADA Services

The relay supports DNP3 (Level 2) and Modbus SCADA protocols as a standard feature on all ERLPhase relays. DNP3 is available through a direct serial link (Port 122) or the Ethernet LAN on top of either TCP or UDP protocols. The Modbus implementation supports both Remote Terminal Unit (RTU) in binary or ASCII modes and is available through a direct serial link. The SCADA communication settings are made in T-PRO Offliner which can be accessed and uploaded to the T-PRO from Relay Control Panel.

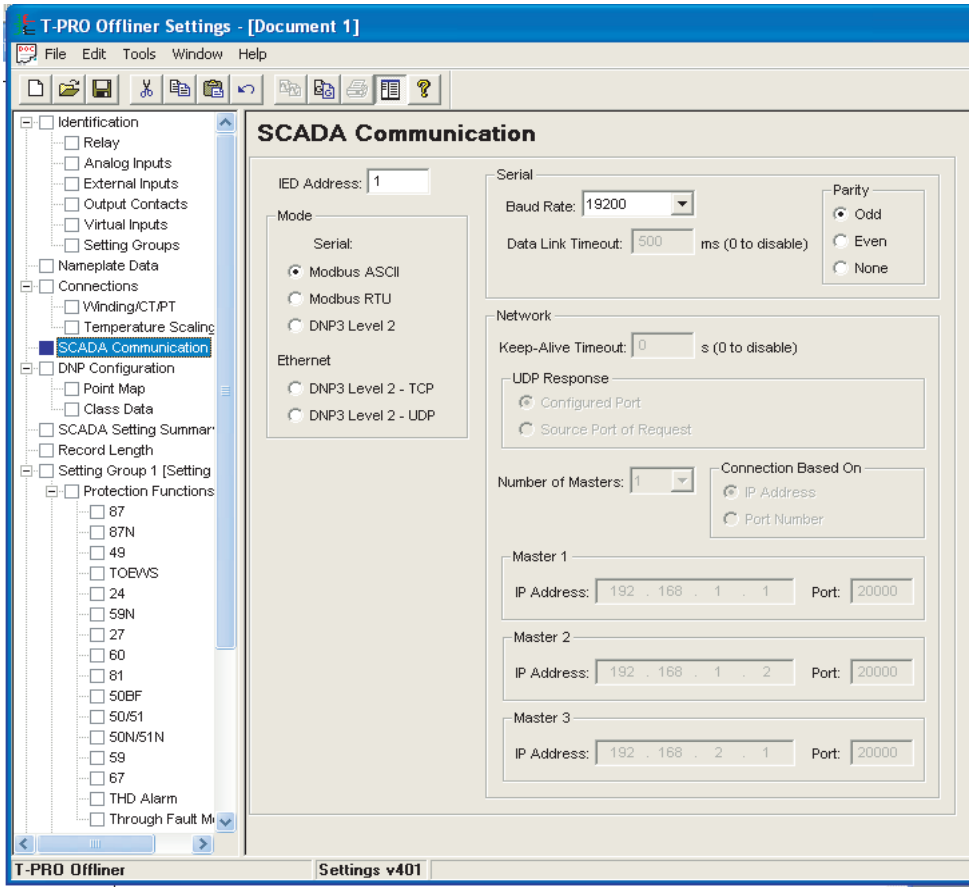


Figure 2.14: SCADA Communication T-PRO Offliner Settings Screen

T-PRO Port 122 is dedicated for use with Modbus or DNP3 serial protocols. Port 122 uses standard RS-232 signaling. An external RS-232↔RS-485 converter can also be used to connect to an RS-485 network.

For details on connecting to serial Port 122 see "Communicating with the T-PRO Relay " on page 2-3 and "Communication Port Details" on page 2-20.

The DNP3 protocol can also be run across the optional Ethernet LAN. Both DNP over TCP and DNP over UDP are supported. For details on connecting to the Ethernet LAN see "Network Link" on page 2-7.

Complete details on the Modbus and DNP3 protocol services can be found in the Appendices. For details see “Modbus RTU Communication Protocol” in Appendix E and “DNP3 Device Profile” in Appendix F.

Protocol Selection

To select the desired SCADA protocol go to T-PRO Offliner SCADA communications section. Select the protocol and set the corresponding parameters.

Communication Parameters

The Port 122 communication parameters are set using the *T-PRO Offliner* > *SCADA Communication* > *Serial* menu in relay’s user interface. Both the baud rate and the parity bit can be configured. The number of data bits and stop bits are determined automatically by the selected SCADA protocol. Modbus ASCII uses 7 data bits. Modbus RTU and DNP Serial use 8 data bits. All protocols use 1 stop bit except when either Modbus protocol is used with no parity; this uses 2 stop bits as defined in the Modbus standard.

Diagnostics

Protocol monitor utilities are available to assist in resolving SCADA communication difficulties such as incompatible baud rate or addressing. The utilities can be accessed through the Maintenance menu in VT100 Terminal mode.

2.13 Communication Port Details

Table 2.4: Communication Port Details

Location	Port	Function
Front Panel	119	RJ-45 receptacle, 100BASE-T Ethernet interface. Default IP = 192.168.100.80 Used for user interface access or 61850 SCADA access or DNP SCADA access through Ethernet LAN.
Front Panel	150	USB-B receptacle, High speed USB 2.0 interface Used for user interface access Default fixed baud rate 115,200 N81 (no parity, 8 data bits, 1 stop bit).
Rear Panel	118	RJ-11 receptacle, Internal modem interface. Default Baud rate 38,400 N81 (no parity, 8 data bits, 1 stop bit)
Rear Panel	119	Rear panel, RJ-45 receptacle or ST type optical receptacle (factory configured). 100BASE-T or 100BASE-FX (1300nm, multimode) Ethernet interface. Same subnet as front panel port 119. Used for user interface access or 61850 SCADA access or DNP SCADA access through Ethernet LAN.
Rear Panel	120	ST type optical receptacle. 100BASE-FX (1300 nm, multimedia) Ethernet interface. Used for user interface access or 61850 SCADA access or DNP SCADA access through Ethernet LAN.
Rear Panel	121	BNC receptacle, IRIG-B Interface. Modulated or un-modulated, 330 ohm impedance.
Rear Panel	122	RS-232 DCE female DB9. Used for Modbus or DNP SCADA communication. Default Setting: 19,200 baud O71 (odd parity, 7 data bits, 1 stop)
Rear Panel	123	RS-232 DCE female DB9. Used for: User interface access through a direct serial connection. Default Setting: 9600 baud N81 (no parity, 8 data bits, 1 stop bit). User interface access through an external modem. The optional ERLPhase Modem Adapter converts this port to a Data Terminal Equipment (DTE) to simplify connection to an external modem. Default Setting: 19,200 baud O71 (odd parity, 7 data bits, 1 stop bit).

Table 2.5: Signal connections to pins on RS-232 Relay Port		
Signal Name	Direction PC<-> Relay	Pin # on the Relay Port
DCD	¬	1
RxD	¬	2
TxD	®	3
DTR	®	4
Common		5
DSR	¬	6
RTS	®	7
CTS	¬	8
No connection		9

Notes:
Relay is DCE, PC is DTE.
Pins 1 and 6 are tied together internal to the relay.

Table 2.6: Cable Pin Connections	
Male DB-9 Cable End for Relay Port	Female DB-9 Cable End for Computer Port
Pin # on Cable	Pin # on Cable
1	1
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9

Table 2.7: Signal name connections to pins on Modem Adapter

Signal Name	Direction Modem <-> Relay	Pin # on the Modem Adapter
DCD	®	1
RxD	®	2
TxD	¬	3
DTR	¬	4
Common		5
DSR	®	6
RTS	¬	7
CTS	®	8
No connection		9

Notes:
Relay (with modem adapter) is DTE, modem is DCE.
Pins 1 and 6 are tied together internal to the relay.

3 Using the IED (Getting Started)

3.1 Introduction

This section provides information on the start-up sequence and ways to interface with the T-PRO. Descriptions of the Front Panel Display, Terminal Mode and Metering Data are provided.

3.2 Start-up Sequence

When the power supply is connected, the following initialization initializing sequence takes place:

Table 3.1: Initialization Sequence

TEST MODE — red LED on	when power applied
RELAY FUNCTIONAL — green LED on	within 5 seconds after power applied
TEST MODE — red LED off then on	within 10 seconds
Front Display — on	on within 20 seconds after power applied
TEST MODE — red LED off	within 20 seconds after power applied

When the Relay Functional LED comes on, it indicates that the DSP is actively protecting the system.

When the test mode LED goes off, the relay is capable of recording and communicating with the user.

3.3 Interfacing with the Relay

The following methods can be used to interface with the relay:

- Front panel display
- Terminal mode (for maintenance and firmware upgrade)
- Relay Control Panel

3.4 Front Panel Display

The intuitive menu system gives access to all settings, fault logs, metering and statuses.

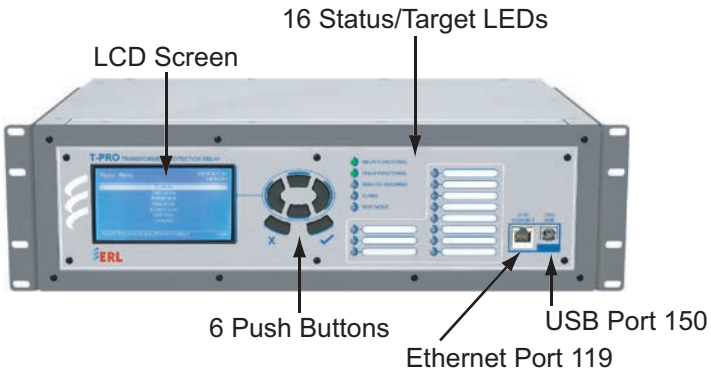


Figure 3.1: Front Panel Display

The LCD screen displays the following metering parameters:

- HV, LV & TV Residual current magnitude and angle (3I0 derived values)
- REF 87N Operating & Restraining current for all the windings (HV REF Operating)

  Current, LV REF Operating Current, TV REF Operating Current, HV REF Restraint

  Current, LV REF Restraint Current, TV REF Restraint Current)
- 3-phase apparent power (MVA - 3ph)
- Power factor (pf - 3ph)
- All sequence voltages
- All sequence currents in all the windings
- Single-phase real power, reactive power, apparent power, Power factor
- 2nd &5th harmonic current value for all the current inputs
- Directional status of 51/67, 51N/67N & 46-51/67

The metering display in LCD screen has a resolution of three decimals for both measured and calculated analog values.

The LCD screen can display analog values both in primary or secondary values.

Table 3.2: T-PRO Front Panel HMI Menu			
Main Screen			
	View / Change / Service : Choice Menu		
	Enter Password		
	Main Menu		(V,C,S)
		System	(V,C,S)
		Relay Identification	(V)
		Relay Comm Setup	(V)
		Settings	(factory)
		Name Plate Data	
		Record Length	
		Setting Group 1	
		Setting Group 2	
		Setting Group 3	
		Setting Group 4	
		Setting Group 5	
		Setting Group 6	
		Setting Group 7	
		Setting Group 8	
		Metering	(V,C,S)
		Analog	(V,C,S)
			Analog Inputs
			IO, IR
			Harmonics
			Trend
		External Inputs	(V,C,S)
		Output Contacts	(V,C,S)
		Logic	(V,C,S)
			Logic Protection 1
			Logic Protection 2
			ProLogic
			Group Logics
			Virtual Inputs
		Records	(V,C,S)

Table 3.2: T-PRO Front Panel HMI Menu			
		View Record List	(V,C,S)
		Fault Record Trigger	(C,S)
		Event Recording	(C,S)
		Trend Recording	(C,S)
	Fault Log		(V,C,S)
		Fault List	
	Event Log		(V,C,S)
		Event List	
	Utilities		(V,C,S)
		Setup	(C,S)
		Timeouts	
		Time Settings	
		Set Manual Time	
		Set DST Time	
		Maintenance	(C,S)
		Output Contacts Control	(S)
		Virtual Inputs Control	(C,S)
		Setting Groups Control	(C,S)
		Erase	(C,S)
		Erase Records	
		Erase Event Logs	
		Network	(V,C,S)
		Network Protocol Stats	(C,S)
		Active Sockets	(C,S)
		Routing Tables	(C,S)
		Ping	(V,C,S)
	LOGOUT		

The display, the 16 LED lights and the 6 push buttons provide selective information about the relay.

LED Lights

Table 3.3: Description of LED Lights	
Relay Functional	When LED is illuminated, indicates that the relay is functional. When the Relay Functional green LED first illuminates, the Relay Inoperative normally closed contact Opens and the protective functions become active.
IRIG-B Functional	When LED is illuminated, indicates the presence of a valid IRIG-B time signal.
Service Required	When LED is illuminated, indicates the relay needs service. This LED can be the same state as the Relay Functional LED or can be of the opposite state depending on the nature of the problem. The following items bring up this LED: DSP failure - protection difficulties within the relay. Communication failure within the relay. Internal relay problems.
Test Mode	Illuminates when the relay output contacts are intentionally blocked. • Possible reasons are: • Relay initialization on start-up User interface processor has reset and is being tested. The user cannot communicate with the relay through the ports until the front display becomes active and the TEST MODE LED goes out. Normally, the red Target LEDs will be off after the start-up unless the relay had unviewed target messages prior to losing power.
Alarm	Illuminates when an enabled relay function picks up. The red Alarm LED should be off if there are no inputs to the relay. If the Alarm LED is on, check the event log messages or *Metering>Logic>Protection Logics* from the front display or on your computer in Relay Control Panel.
Target LEDs	**Descriptions**
1 – 11	Each of the 11 target LEDs is user configurable for any combination of Protection trips or ProLogic element operation.

Phase segregated Trip LED Indications (user configurable) are available for the following functions:

- Differential 87
- Backup Over current 50/51
- Backup Earth fault 50N/51N
- Directional Over current 67
- Directional Earth fault 67N
- Overvoltage & Undervoltage 27/59

Push Buttons

Table 3.4: Identification of Push Buttons	
Up, Down, Right, Left, Enter, Escape	Used to navigate the front panel screens.

Display

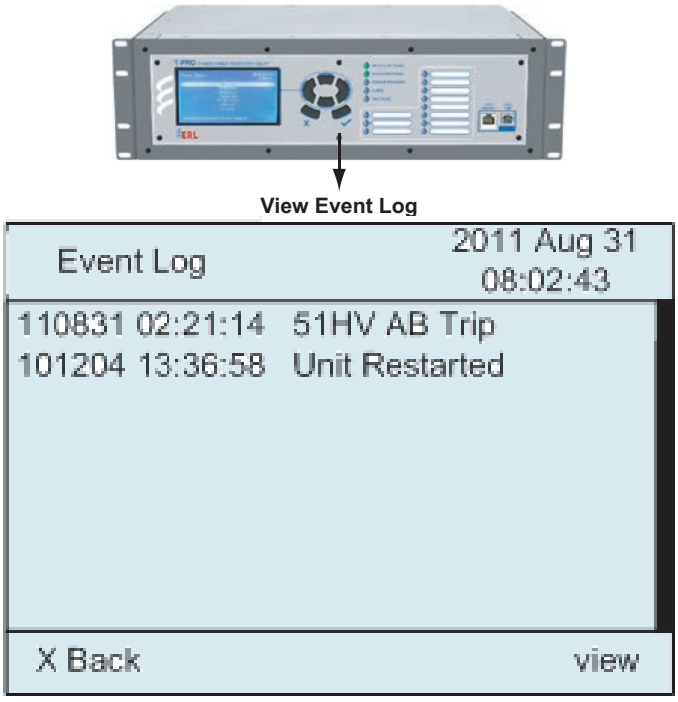


Figure 3.2: Display Examples

Table 3.5: T-PRO Front panel Display Messages
See full list of display items in Table 3.2: T-PRO Front Panel HMI Menu on page 3-3.

3.5 Terminal Mode

The terminal mode is used to access the relay for maintenance and firmware upgrade functions.

See “Using HyperTerminal to Access the Relay’s User Interface” in Chapter 2 section 2.9 and “Firmware Update” in Chapter 2, section 2.10.

3.6 Relay Control Panel

RCP is used for all user interface. A short description of the RCP configuration to connect to a relay is given here. Please refer to the Relay Control Panel User Manual for details.

Follow this sequence to configure RCP for USB link to the relay.

1. Execute.

   Relay Control Panel.exe

2. Execute.

   T-PRO 4000 Offliner.exe

3. Install Null Modem Driver.

   Please refer to the Relay Control Panel User Manual for details.

4. Run Relay Control Panel.

   Go to:

   Start > All Programs > ERLPhase > Relay Control Panel > Relay Control Panel

   First time RCP is run.

   Hit *Add New*.

   “Add New Relay”

   Choose Communication > Direct Serial Link.

   Hit *Get Information From Relay.*

   Then RCP will communicate with the TPRO-4000 and retrieve information to fill required fields.

   When this is done, hit *Save Relay*.

   If the window “Relay already exists...” pops up, you may need to rename the relay changing the “Relay Name” in the “Relay Definition” category, before saving.

   After first time, in “Select Relay”, choose relay and hit *Connect*.

   In “Relay Password Prompt”

   Choose desired access level, enter appropriate password

   Note: Default passwords are listed below (remove the quotation marks)

   View Access “view”

   Change Access “change”

   Service Access “service”

The RCP displays the following metering parameters:

- HV, LV & TV Residual current magnitude and angle (3I0 derived values)
- REF 87N Operating & Restraining current for all the windings (HV REF Operating Current, LV REF Operating Current, TV REF Operating Current, HV REF Restraint Current, LV REF Restraint Current, TV REF Restraint Current)
- 3-phase apparent power (MVA ? 3ph)
- Power factor (pf - 3ph)
- All sequence voltages
- All sequence currents in all the windings
- Single-phase real power, reactive power, apparent power, Power factor
- 2nd &5th harmonic current value for all the current inputs
- Directional status of 51/67, 51N/67N & 46-51/67

The metering display in RCP has a resolution of three decimals for both measured and calculated analog values.

The basic structure of the Relay Control Panel information, including basic actions available, is given below:

Table 3.6: Relay Control Panel Structure

			View	Change	Service
Relay Control Panel					
	Records			Trigger Fault	Trigger Fault
				Trigger Swing	Trigger Swing
				Trigger Event	Trigger Event
	Faults			Clear Faults	Clear Faults
	Events			Erase	Erase
	Metering				
		Analog			
		IO, IR			
		Harmonics			
		Trend, D49			
		External			

Table 3.6: Relay Control Panel Structure				
	Logic 1			
	Logic 2			
	ProLogic			
	Outputs			
	GroupLogic			
	Virtual			
Utilities				
	Unit Identification			
	Communication			
	Time			
	Analog Input Calibration	N/A	N/A	
	External Input			
	Settings Group		Save	Save
	Password	N/A	N/A	
	Virtual Inputs	N/A	Latch/Pulse	Latch/Pulse
	Loss of Life		Save	Save
	Through Fault		Save	Save
	Clear Trend Log		Save	Save
Configuration				
	Present Settings	(Get From Relay)		
	Saved Settings		(Load to Relay)	(Load to Relay)

Notice that some options are not available (N/A) depending on the access level.

4 Protection Functions and Specifications

4.1 Protection and Recording Functions

This section describes the equations and algorithms of the T-PRO protection functions, the recording functionality and programming of the Output Matrix.

All functions with time delay provide an alarm output when their pick up level is exceeded. All functions use the fundamental component of the analog inputs, except for THD Alarm and harmonic restraint of the 87 function.

87 Differential Protection

Differential protection is the most universally applied form of transformer protection. The electrical area enclosed within the High Voltage (HV), Low Voltage (LV) and Tertiary (TV) side CTs define the zone of protection. The element uses a percent restraint slope characteristic where the sensitivity of the element has in inverse relationship to the fault level, in particular for faults external to the transformer zone (i.e., through faults). The slope characteristic is a general requirement of differential protection due to various CT ratio, angle and saturation errors that tend to magnify at higher fault levels. Figure 4.1: on page 4-1 shows the differential slope characteristic in the relay.

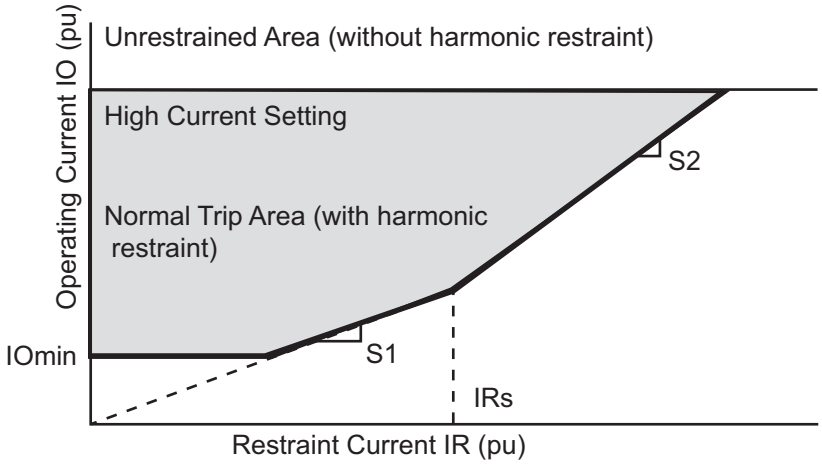


Figure 4.1: Differential Protection Slope Characteristic

Operating Current = IO = $|I_{HV} + I_{LV} + I_{TV}|$ for each of phases A, B and C (i.e., Operating Current is the phasor sum of all transformer windings). (1)

where

I_{HV} is the current from the high voltage side

I_{LV} is the current from the low voltage side

I_{TV} is the current from the tertiary side

$$\text{Restraint Current (IR)} = [\ |I1x| + |I2x| + |I3x| + |I4x| + |I5x|\ ] / 2 \quad (2)$$

where *x* represents phase A, B or C for each of 5 sets of current inputs

In order to allow a more sensitive yet secure differential setting, the T-PRO slope characteristic is supplemented with Delta Phase and Rate of Change of Differential (ROCOD) supervision. Descriptions of these supervisions are provided later in this section.

Transformer Energizing Inrush Restraint (2nd Harmonic)

Second harmonic current is present in the magnetizing inrush current of an unfaulted transformer being energized. Since inrush current is typically greater than the 87 trip setting, a high ratio of the 2nd harmonic to fundamental current is used to restrain the 87 when no fault is present.

The 2nd harmonic restraining only occurs if the calculated IO and IR currents are in the 87 Normal Trip Area. However, if the IO exceeds the High Current Setting, then the 2nd harmonic will not be examined and the trip will not be blocked. Typical I2 setting for 2nd harmonic restraint is 0.05 to 1.00 per unit.

Note that the T-PRO will not calculate a harmonic restraint value if the fundamental current is less than 5% of nominal. Therefore care must be taken to ensure that the IOmin setting is always set above 0.25 A for a 5 A relay or 0.05 A for a 1 A relay. This calculation should be performed on each CT input.

I2 Cross Blocking

When I2 Cross Blocking is enabled (default), the 2nd harmonic restraint blocks the 87 trip when the ratio I2nd / Ifundamental exceeds the I2 setting in any phase.

When I2 Cross Blocking is Disabled, the 2nd harmonic restraint will block the 87 trip only if the ratio

I2nd / Ifundamental exceeds the I2 setting in at least two phases.

For three-phase transformer application, I2 Cross Blocking is typically enabled.

For three single-phase transformer applications, the I2 cross-blocking is usually disabled to ensure the transformer will trip correctly if energizing onto a fault. Since the 2nd harmonic calculation is carried out on the internal zero sequence eliminated delta currents, any single-phase fault will produce predominantly fundamental fault current in two phases, thereby allowing the relay to trip correctly.

As shown in Figure 4.2: on page 4-3, the 2nd harmonic restraint signal is stretched for 5 milliseconds in the first cycle upon transformer energization. This stretch timer prevents possible momentary reset of the 2nd harmonic blocking signal due to the current transition in the first cycle. Note that this logic only becomes active when the transformer is de-energized or very lightly loaded for more than 10 seconds.

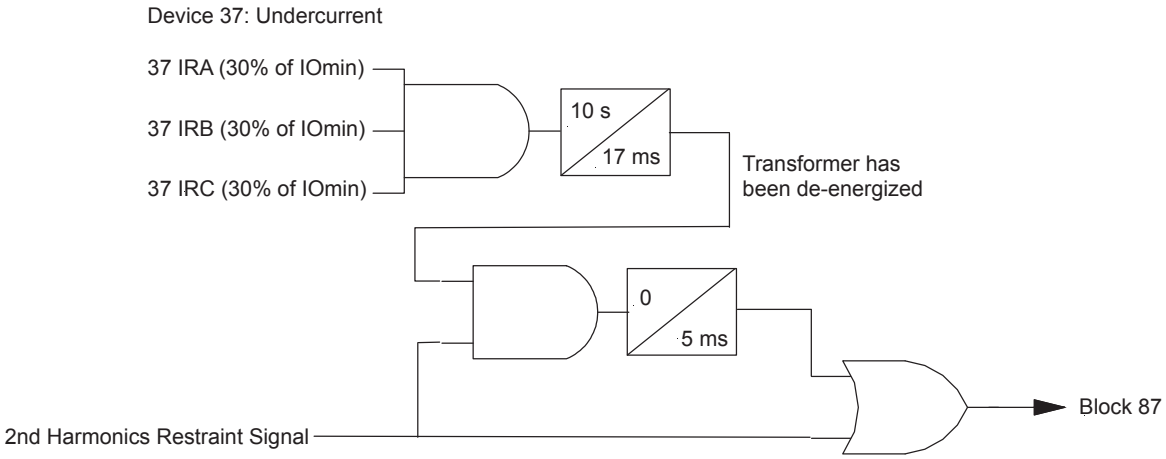


Figure 4.2: Second Harmonic Restraint Logic

Over-fluxing Restraint (5th Harmonic)

The presence of a significant amount of 5th harmonic current in a transformer is typical due to over-fluxing caused by an overvoltage or low frequency condition. Overfluxing may produce unbalanced currents in the transformer that could cause a false differential current. If 5th harmonic restraint is Enabled, then a high ratio of 5th harmonic current to fundamental current will block the 87 trip. The 5th harmonic blocking will only occur if the calculated operate and restraint currents are in the normal trip area. If the operate current exceeds the High Current Setting, then the 5th harmonic will not be examined and the trip will not be blocked.

Typical setting for 5th harmonic restraint is 0.05 to 1.00 PU.

Table 4.1: 87 Transformer Differential Setting Functions	
IO_{min}	Per unit minimum current that operates the device 87.
IRs	Per unit point on the restraint axis of the differential characteristic where Slope 1 and Slope 2 intersect.
S1	Slope of first part of characteristic meeting IOmin and Slope 2.
S2	Slope of second part of characteristic which meets the end of Slope 1 and the High Current Unrestrained Setting.
I2	Ratio of 2nd harmonic current to fundamental to provide energizing harmonic restraint.
I5	Ratio of 5th harmonic current to fundamental to provide transformer overexcitation harmonic restraint.
High Current Setting	Per unit level of the unrestrained high set differential; operates if a heavy fault occurs in the transformer, irrespective of harmonic content.

Table 4.2: 87 Transformer Differential Setting Ranges	
87 Transformer Differential	Enable/disable
IO_{min} (per unit)	0.10 to Minimum of (IRs * S1/100, 1.00)
IRs (per unit)	(IOmin * 100/S1) to 50.00
S1 (%)	IOmin * 100/IRs to Minimum of (S2, 100)
S2 (%)	Maximum of (S1, 30) to 200
High Current Setting (per unit)	3 * IOmin to 100.00
I2 Cross Blocking	Enable/Disable
I2 Setting (per unit)	0.05 to 1.00
I5 Restraint	Enable/disable
I5 Setting (per unit)	0.05 to 1.00

HV, LV and TV winding current calculations

The T-PRO has 5 sets of three-phase current inputs that can summed to obtain the total current flowing into or out of a transformer winding. The inputs can be configured for use with CTs of different ratios and connections. This flexibility requires that certain mathematical corrections be carried out on the currents prior to summing them in order to derive the total winding and transformer current. This process includes three steps:

1. Selection of a reference current input
2. Phase Corrections

3. Magnitude Corrections

The three steps are described in the following sections.

1. Selection of reference current input

The reference current (at 0) is fixed as the Transformer Winding where the Potential Transformer is connected. The reference transformer winding will always be either Wye 0 or Delta 0. All causes of current phase shift, due to connections of the transformer and/or CTs, shall be corrected in the relay algorithm to be in phase with the reference. Consider the following example in Figure 4.3: on page 4-5:

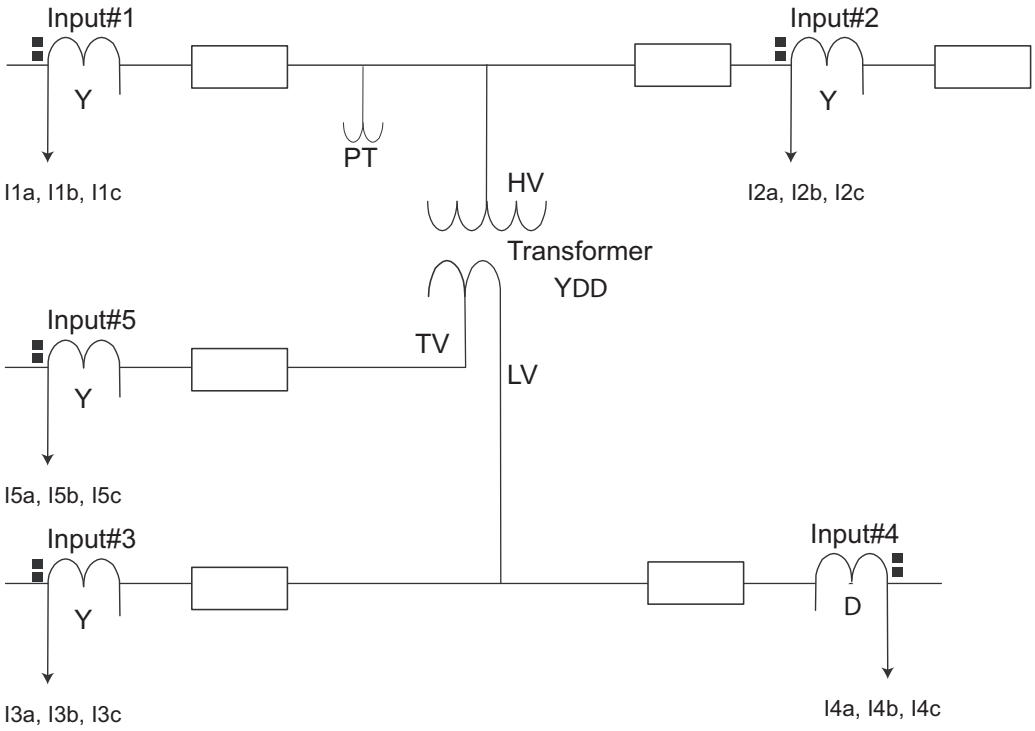


Figure 4.3: Example of 3-Winding Transformer Application Using 5 Inputs

For this example, the PT is selected as being on the HV side, therefore the HV main transformer winding is the reference, fixed at Wye 0. If the PT had been on the LV side then the LV main transformer winding would be the reference Delta 0. We continue with the example, still assuming that the PT is on the HV side.

2. Phase Corrections

There are two phase corrections required, one for the transformer winding and one for CT connections. Rather than correcting both separately, the total correction required on each winding/CT combination is determined. Although the reference transformer winding is fixed at 0, it still must be added to its CT angle to obtain the total winding angle to be corrected. For example, in our example connection CT#2 has a 180 shift and is connected on the 0 reference

winding; therefore the sum of HV winding and CT#2 combination is 0 + 180 = 180. The total angle of 180 must be compensated by -180.

Based on the example of for details see Figure 4.3: Example of 3-Winding Transformer Application Using 5 Inputs on page 4-5, the descriptions of the corrections required to normalize the current of each input are in.

Table 4.3: Example, Transformer Current Correction

Winding	Voltage (KV)	XFMR Winding	XFMR Winding Phase	Curr. Input	Physical CT Conn.	CT Phase	CT Turn's Ratio	CT Ratio With Factor	Total Phase Shift	Phase Correction Required
HV	230	Y	0^0(ref)	#1	Y	0^0	200 :1	200 :1	0^0	0^0
				#2	Y	180^0	250 :1	250 :1	180^0	-180^0
LV	115	Δ	-30^0	#3	Y	0^0	400 :1	400 :1	-30^0	$+30^0$
				#4	Δ	-30^0	450 :1	258.8 :1	-60^0	$+60^0$
TV	13.8	Δ	$+30^0$	#5	Y	0^0	4000:1	4000:1	$+30^0$	-30^0

Observe that CT input 4 in our example is connected in a delta configuration. Currents from delta CTs are √3 larger than from Y connected CTs at the relay. The T-PRO will automatically take the delta CT setting into account and correct for the √3 factor.

The formulas for the phase shift corrections are in "Current Phase Correction Table" in Appendix L.

Our example of Table 4.3: on page 4-6 would use the following Current Phase Correction formulas (from "Current Phase Correction Table" in Appendix L).

Table 4.4: Example

Input 1 0^0 Correction	Input 2 180^0 Correction	Input 3 30^0 Correction	Input 4 60^0 Correction	Input 5 -30^0 Correction
$IA = \frac{2Ia - Ib - Ic}{3}$ $IB = \frac{-Ia + 2Ib - Ic}{3}$ $IC = \frac{-Ia - Ib + 2Ic}{3}$	$IA = \frac{-2Ia + Ib + Ic}{3}$ $IB = \frac{Ia - 2Ib + Ic}{3}$ $IC = \frac{Ia + Ib - 2Ic}{3}$	$IA = \frac{Ia - Ib}{\sqrt{3}}$ $IB = \frac{Ib - Ic}{\sqrt{3}}$ $IC = \frac{Ic - Ia}{\sqrt{3}}$	$IA = \frac{Ia - 2Ib + Ic}{3}$ $IB = \frac{Ia + Ib - 2Ic}{3}$ $IC = \frac{-2Ia + Ib + Ic}{3}$	$IA = \frac{Ia - Ic}{\sqrt{3}}$ $IB = \frac{Ib - Ia}{\sqrt{3}}$ $IC = \frac{Ic - Ib}{\sqrt{3}}$

The process of correcting current angles mathematically creates virtual "Delta" connections from the current inputs. Another benefit of this process is the elim-

ination of zero sequence current, leaving only positive sequence and negative sequence currents as operating quantities. We will refer to these compensated currents as Delta Compensated Currents as we progress through the example.

3. Magnitude Mismatch Corrections

The next step is to correct the ratio mismatch of each current input. There are three ratio corrections required:

- CT Ratio Mismatch Correction
- CT Connection Correction
- Transformer Ratio Correction

The Magnitude Mismatch Correction Factor is applied on each current input referenced to the first CT input on the transformer reference side as follows:

$$\text{Magnitude\_Mismatch\_Correction\_Factor}[i] = \frac{PhysicalCTRoot3Factor[i] \times VoltageLevel[i] \times CTRatio[i]}{PhysicalCTRoot3[REF] \times Voltage[REF] \times CTRatio[REF]} \quad (3)$$

where

i = current input being considered

PhysicalCTRoot3Factor[i] = 1.0 for a Y connected CT, 1/√3 for Delta connected CT

VoltageLevel[i] = Voltage level of the input being considered

CTRatio[i] = CT ratio of the input being considered

Voltage[REF] = Primary voltage level of the reference (PT) side

CTRatio[REF] = CT ratio of the first current input on the reference (PT) side

After the three corrections steps are complete, the phase and mismatch corrections have been performed. The Delta Compensated Currents can now be summed on a single-phase basis to arrive at the HV, LV and TV winding currents that shall be used in the differential function.

For our example:

HV has A, B, C inputs from two CTs connected to T-PRO current input sets I1 and I2.

LV has A, B, C inputs from two CTs connected to T-PRO current input sets I3 and I4.

TV has A, B, C current from one CT connected to T-PRO current input set I5.

The relay calculates the HV, LV and TV Delta Compensated Currents for use in the 87 function of our example as follows:

IHVa = I1A + I2A	ILVa = I3A + I4A	ITVa = I5A
IHVb = I1B + I2B	ILVb = I3B + I4B	ITVb = I5B
IHVc = I1C + I2C	ILVc = I3C + I4C	ITVc = I5C

Note regarding delta compensated currents used in other T-PRO functions.

Overcurrent (OC) and Overload (OL) Functions 50/51, 67, 49 and TOEWS also may (or may not) use Delta Compensated Currents, depending on which of the following CT connections apply:

•If any of the CTs associated with the particular OC or OL function are connected in Delta, then the relay uses Delta Compensated Currents in the function.

•If all of the CTs associated with the particular OC or OL function are connected Wye, then the relay shall use the Wye Currents (i.e., currents without zero sequence elimination phase shift being applied).

In our example connection of Figure 4.3: on page 4-5, the OC and OL functions applied on the HV side use Wye Currents (i.e., not Delta Compensated) since both CTs on the HV winding are using Wye CTs.

However, in the same example any the OC and OL functions used on the LV side must use Delta Compensated Currents, because at least one of the CTs used on the LV side is connected in a Delta configuration.

Delta Phase Dot Product Differential Supervision (Patent Pending)

The slope characteristic of the transformer differential operates on Kirchoff's current principle. This principle states that for any current entering a node (or in our case transformer zone), there must be equal current leaving the zone if no faults are present within the zone. The protected zone is defined as the area between all of the CTs that are used to measure each and every current entering or leaving the transformer zone.

In the ideal situation the differential slope characteristic could be set to securely produce a differential trip only for internal faults. However in practice, CT current measurement errors caused by CT saturation, DC offsets or sympathetic inrush of parallel transformer banks can disrupt this current measurement balance and could cause the relay to trip incorrectly during normal operations or external faults.

Analysis of extensive dynamic simulations has shown that even with current distortion due to a variety of measurement error factors, the phase angle of the current is maintained. Therefore, phase angle differences can be used to reliably identify faults as being internal or external to the transformer zone; this fact is the basis of the Delta Phase Dot Product (DPDT) algorithm. Note that DPDT cannot produce a trip output on its own; it can only give the differential slope characteristic permission to trip.

The current angles of the faulted and unfaulted phase current inputs for an external fault are close to 180 degrees apart. However, since it's recognized that there could be CT phase angle errors, the boundary condition has been set conservatively to ±90 degrees. This boundary is fixed and has no user settings associated with it.

DPDT is performed on a per-phase basis on the HV, LV and TV Delta Compensated Currents (i.e., HVA, LVA, TVA are compared only to each other, HVB, LVB, TVB are compared only to each other, HVC, LVC, TVC are compared only to each other.)

The relay checks to see if the compared currents are more or less than 90 from each other. If all compared currents are within the 90 or less of each other, the relay recognizes the condition as an Internal fault. If the difference current also enters the trip area of the slope characteristic, the 87 will trip.

However, if one or more the currents are greater than 90 from any of the other compared currents, this is recognized as an External fault and the 87 will be Blocked from tripping, even if the difference current enters the trip area of the slope characteristic.

The method used to compare current angles is the mathematical dot product. This concept makes use of the angular relationship present in Kirchhoff's current law.

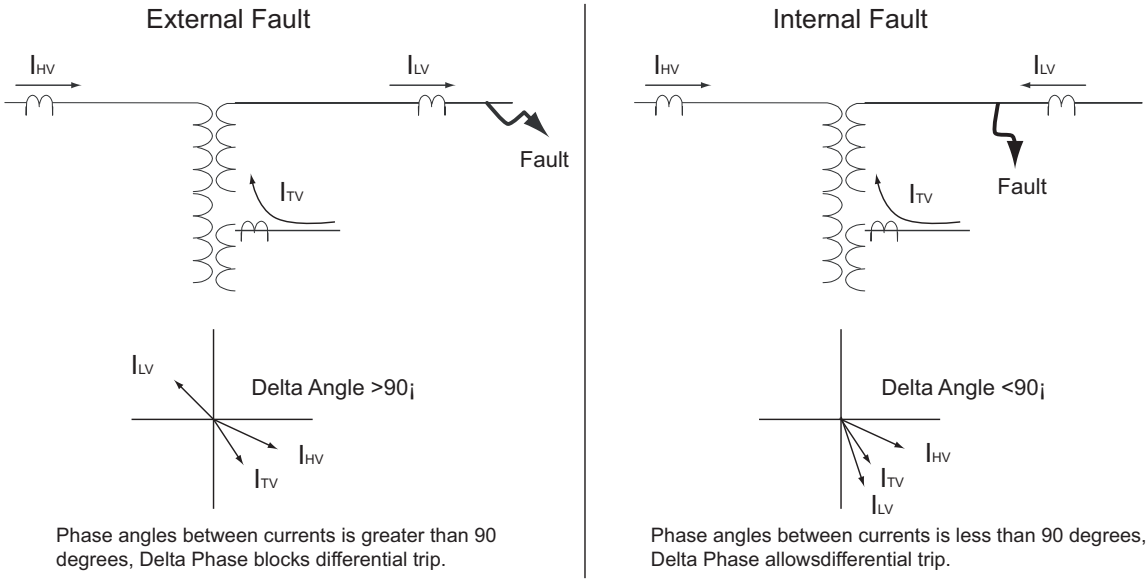
In mathematical terms, if Phasor A and Phasor B are considered, then: A * B = AB Cos ()

Where: (theta) is the angle between the two phasors.

Phasors A and B are normalized to a value of 1.0 and then the dot product is applied and analyzed:

- Any >90, the dot product will be negative (Block 87 trip).
- All <90, the dot product will be positive (allow 87 trip).

To ensure the current phasor has enough magnitude to be reliably used, a current level detector for each current input is fixed at 5% of $I_{nominal}$ (i.e., 0.25 A for 5 A nominal, 0.05 A for 1 A nominal relay). If any current is below the 5% threshold, the current angle will not be calculated in DPDT. In the case where only one current input is above this current threshhold (such as when energizing an offline transformer), the DPDT algorithm will not inhibit the 87 slope. This means that if a transformer fault occurs upon energization or if a permanent fault is present, the T-PRO will trip correctly. Figure 4.4: illustrates transformer internal and external faults and the current angle comparisons.



Phase angles between currents is greater than 90 degrees, Delta Phase blocks differential trip.

Phase angles between currents is less than 90 degrees, Delta Phase allowsdifferential trip.

Figure 4.4: Delta Phase Dot Product supervision for External and Internal Fault Conditions

Rate of Change of Differential Supervision (ROCOD)

If the positive rate of change of IO (IOperate) exceeds the positive rate of change of IR (IRestrain) within the first cycle of a fault, ROCOD supervision will allow the 87 to trip if the fault goes into the trip area of the Slope characteristic.

Figure 4.5: Rate Of Change Of Operating And Restraint Quantities shows how the dio/dt and the dIr/dt quantities vary during an internal and during an external fault. Normally, for an internal fault, the dIo/dt quantity will be greater than the dIr/dt quantity. On the other hand, if an external fault occurs, dIo/dt will be less than dIr/dt.

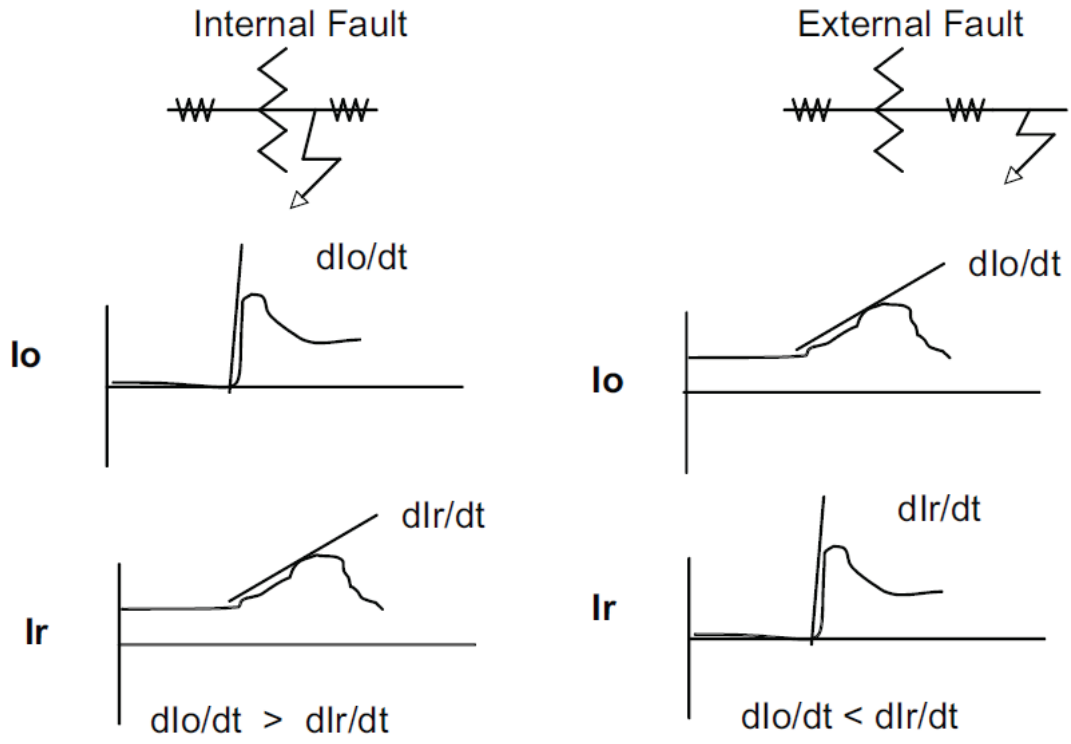


Figure 4.5: Rate Of Change Of Operating And Restraint Quantities

All of the components of the T-PRO differential function are summarized in Figure 4.6: Transformer Differential Protection Logical Overview .

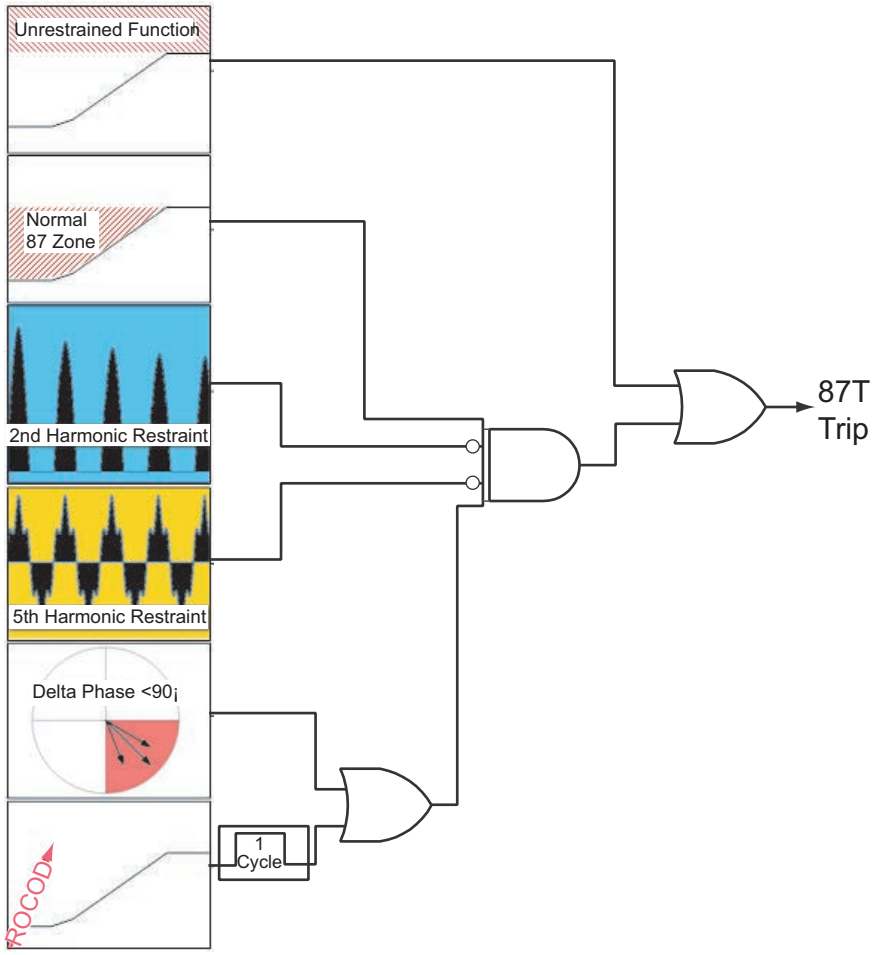


Figure 4.6: Transformer Differential Protection Logical Overview

87N Neutral Differential

Neutral Differential protection (87N), which is also called Restricted Earth Fault, provides sensitive protection of the transformer or auto-transformer for internal winding to ground faults. The function is restricted to detecting ground faults only within the zone between by the CTs that define the 87N zone.

Since the phase differential (87) operates only on positive and negative sequence currents, it may not be sensitive enough to detect all internal ground faults, especially on the lower 1/3 of the transformer winding. However, the 87N operates on zero sequence current only and has good sensitivity for detecting these faults.

To intentionally limit the current for winding to ground faults a ground resistor is often connected between the transformer neutral and ground. It should be noted that the grounding resistance can reduce the sensitivity of 87N by an amount that can be calculated.

The principle of operation of the 87N is to compare the phasor of the transformer neutral current (IN) to the phasor of the residual of the winding's 3-phase currents (3I0). Again using Kirchoff's law, if these are not equal and subtractive, then there is an internal ground fault on that winding.

Note the winding 3-phase CTs must be Wye connected. Delta CT's cannot be used as they would trap the zero sequence current making it unavailable to the 87N function.)

The 87N characteristic consists of a slope characteristic and Delta Phase Dot Product supervision.

The 87N function can be used on a normal grounded transformer connection, a delta connected transformer winding with a grounding bank contained within the its zone or on an auto-transformer.

87N Operating Current (IO)

For a Regular Wye Transformer: $IO = |IA + IB + IC + IN|$ (4)

For an Auto-Transformer: $IO = |HV_{3I0} + LV_{3I0} + IN|$ (5)

87N Restraint Current (IR)

For a Regular Wye Transformer: $IR = (|IN| + |IA + IB + IC|) / 2$ (6)

For an Auto-Transformer: $IR = (|HV_{3I0}| + |LV_{3I0}| + |IN|) / 2$ (7)

IA, IB and IC are the phase currents,

Where
IN is the current from the neutral CT
3_{I0} is the residual derived from the 3-phase currents of the respective winding(s)
And where:
Operate current IO = 0 (ideally) for external ground faults
Operate current IO > 0 for internal ground faults

Note: All current reference directions for any 87 or 87N function are into the transformer.

For an auto-transformer, the HV_{3I0} and LV_{3I0} are normalized by the CT ratios on both sides of the transformer to derive each primary current. The normalized currents are then directly summed. The different voltage levels need not be considered for the 87N of an auto-transformer. The per unit settings are calculated using the side with the PT as the base.

The 87N base current is calculated as:

(1000 * MVA) / (sqrt (3) * Ref_Side_kVL-L) (8)

The differential currents are calculated as:

IO (pu) = IO primary amps / Ibase (9)

IR (pu) = IR primary amps / Ibase (10)

The settings depend on the value of the neutral grounding resistor (if used) and assumptions regarding CT saturation for external faults.

Table 4.5: 87N Neutral Differential Setting Functions	
IO_{min}	Per unit minimum level that operates the device 87N.
IRs	Per unit point on the restraint axis of the differential characteristic where Slope 1 and Slope 2 intersect.
S1	Slope of first part of characteristic meeting IOmin and Slope 2.
S2	Slope of second part of characteristic meeting Slope 1

Table 4.6: 87N Neutral Differential Setting Ranges	
HV, LV, TV	Enable/Disable
IO_{min} (per unit)	0.10 to Min (IRs * S1/100, 1.00)
IRs (per unit)	(IOmin * 100/S1) to 50.00
S1 (%)	IOmin * 100/IRs to Min(S2, 100)
S2 (%)	Max(S1, 30) to 200
CT Turns Ratio	1.00 to 10000.00

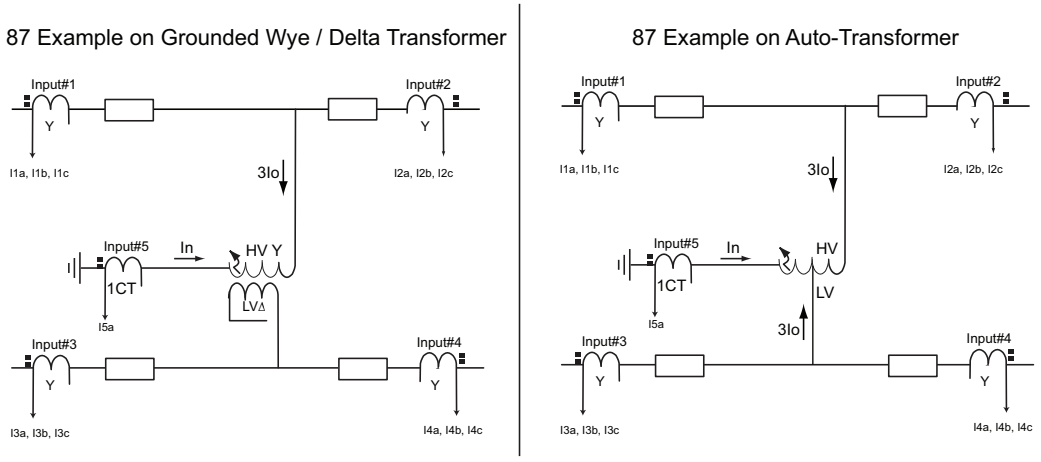
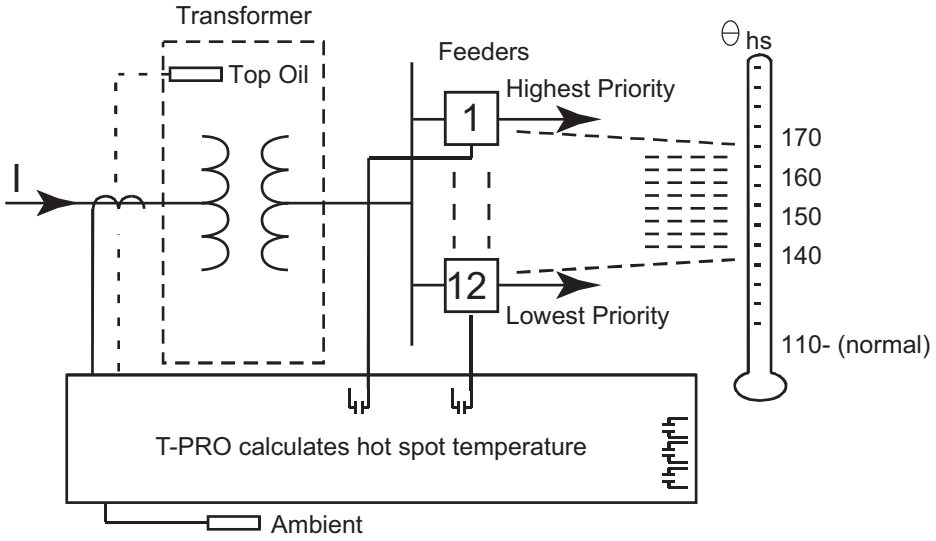


Figure 4.7: 87N Application Examples

Note: Only 87N-HV function is available for auto-transformer application.

49-1 to 49-12 Thermal Overload



Other Functions: SCADA Alarm, Block Tapchanger, Prevent Load Restoration, etc.

Figure 4.8: 49-1 to 49-12 Thermal Overload Modules

Thermal overload protection protects the transformer windings from excessive insulation damage due to heavy loading and/or high temperature conditions. There are 12 identical devices that use a combination of current and temperature monitoring to shed and to restore load based on the level of current in the winding and/or the temperatures inside the transformer.

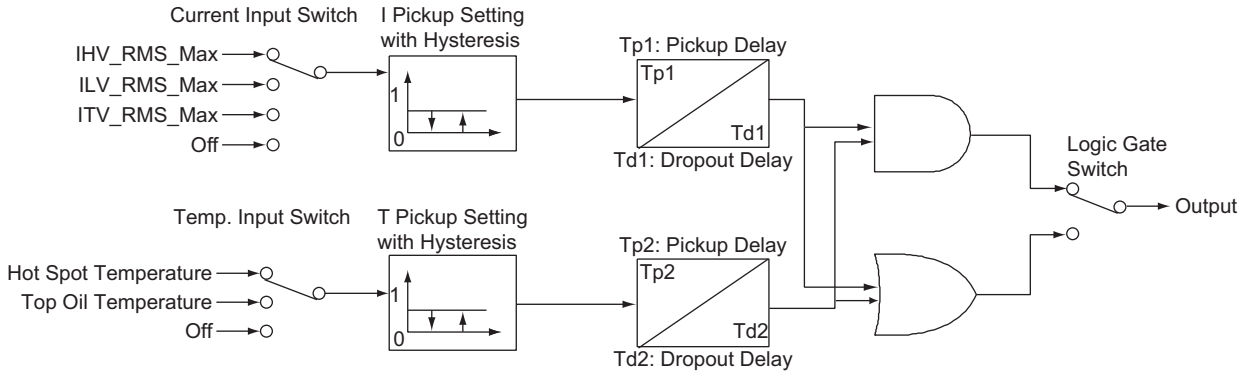


Figure 4.9: Thermal Overload Protection Logic Diagram

Figure 4.9:shows the components of the 49 Thermal Overload function. The Current Input Switch activates the current based portion of the 49 device which is used to detect high loading conditions of any of the transformer windings. The 49 tolerates the thermal overload for a specified definite time before the element operates. When the loading drops below the 49 pickup, the hysteresis

maintains the output until the current drops further, below the level determined by the hysteresis setting, for the duration of the dropout delay timer.

The Temperature Input Switch activates Top Oil temperature or the Hot Spot temperature protection. Top Oil temperature may be either sensed or calculated and the Hot Spot temperature is calculated based on inputs. The settings are made in a similar fashion to the current settings with pickup and hysteresis levels and pickup and dropout delay settings. In this manner the temperature based portion of the 49 device monitors the internal temperatures of the transformer and tolerates them for a specified time.

A Gate Switch setting provides two logical states where the Current and Temperature elements can be combined using AND/OR logic to monitor different parts of the transformer under different loading and temperature conditions.

You can set each individual 49 device to provide a simple Alarm LED or one of the 11 programmable target LEDs. Additional 49 operating information is available on the HMI display, in Relay Control Panel and recording.

Note that the current used in the 49 function may be the uncompensated Wye currents, or Delta Compensated currents. For more information, see “Note regarding delta compensated currents used in other T-PRO functions.” on page 4-8.

Table 4.7: 49 Thermal Overload Setting Ranges

Current Input Switch	Off, HV, LV, TV
Pickup (per unit)	0.10 to 20.00
Hyteresis (per unit)	0.00 to 1.00
Pickup Delay (Tp1, seconds)	0.00 to 1800.00
Dropout Delay (Td1,seconds)	0.00 to 1800.00
Temperature Input Switch	Off, Hot Spot, Top Oil
Pickup (degrees Celsius)	70.0 to 200.0
Hysteresis (degrees Celsius)	0.0 to 10.0
Pickup Delay (Tp2, hours)	0.00 to 24.00
Dropout Delay (Td2, hours)	0.00 to 24.00
Logic Gate	OR or AND

49TOEWS Transformer Overload Early Warning System

TOEWS feature extends the thermal overload concept of the previous section in two ways:

- Predicts excessive hot spot temperature to thirty minutes in advance.
- Predicts excessive loss of life to thirty minutes in advance.

Both of these are based on the availability of an adequate thermal model of the transformer. For details see “Top Oil and Hot Spot Temperature Calculation” in Appendix N. To use this feature the relay must have an ambient temperature probe.

Note that the current used in the TOEWS function may be the uncompensated Wye currents, or Delta Compensated currents. For more information, see “Note regarding delta compensated currents used in other T-PRO functions.” on page 4-8.

Excessive Hot Spot Temperature Warning

Enabling this feature, hot spot temperature is calculated at every time step (five seconds) into the future. The assumption is that the load current and ambient temperature do not change.

If this calculation indicates that the hot spot temperature exceeds its trip setting, the following happens:

15-minute warning alarm is activated when the calculated time is fifteen minutes or less.

30-minute warning alarm is activated when the calculated time is between thirty minutes and fifteen minutes.

Trip output is activated if the calculated time is zero.

The actual time to trip, in minutes, is also available (30, 29,...1, 0 minutes). If the time to trip is greater than 30 minutes, the display value is “+++++”.

Excessive Loss of Life Warning

This feature overcomes a difficulty of using simple over-temperature as an indication of overload.

If the hot spot temperature trip setting is 140°C and the temperature hovers at values just below that level, then damage to the cellulose insulation occurs, but no trip occurs. Also, if the temperature briefly exceeds the setting (less than an hour) and then falls back to normal levels, a trip should not occur, but will.

You can overcome these unreliability and security issues by using the “Loss of Life” concept. The calculation is outlined in “Top Oil and Hot Spot Temperature Calculation” in Appendix N.

The 30-minute warning, 15-minute warning and trip outputs occur if either the hot spot temperature or Loss of Life limits are exceeded.

The three settings are:

THS Trip Setting

Use 175°C with Loss of Life protection enabled. The Loss of Life setting will not allow temperatures near this level to last too long.

If Loss of Life protection were not enabled, then a lower setting would be necessary, say 140°C, a temperature at which oil bubbles might start to form, depending for one thing on the oil's water content.

THS To Start Loss of Life Calculation

For 65°C rise transformers the normal hot spot temperature is 110°C. Therefore, some value above this is appropriate for the start of "Excessive Loss of Life" calculation initiation. Select 125°C.

Loss of Life Trip Setting

Select 2 days as the setting. This, in combination with the above, allows overloads similar to those recommended in the Standard (C57.91-1995).

A study for this transformer shows that for these settings, a sudden overload will trip due to hot spot temperature for times less than about 15 minutes, and due to excessive loss of life for times greater than about 15 minutes. The software program to assist in this kind of study is available from ERLPhase.

Table 4.8: TOEWS Transformer Overload Early Warning System Setting Ranges

TOEWS	Enable/Disable
THS (Temperature Hot Spot) Trip Setting (degrees Celsius)	70.0 to 200.0
THS to Start LOL (Loss of Life) Calculation (degrees Celsius)	70.0 to 200.0
LOL (Loss of Life) Trip Setting (days)	0.5 to 100.0

24 Overexcitation

The T-PRO provides 3 overexcitation elements, one inverse time (24INV), and the other 2 are definite time (24DEF-1 and 24DEF-2).

24INV provides inverse-time overexcitation (over-fluxing) protection due to high system voltages or frequency deviations. The operating quantity is the ratio of voltage to frequency because flux is proportional to the voltage and inversely proportional to the frequency.

The element uses the positive sequence voltage and compares the per unit positive sequence voltage magnitude to the per unit positive sequence frequency.

24INV delay characteristic is defined as:

$$T = \frac{K}{\left(\frac{V}{f} - Pickup\right)^2} \tag{11}$$

where:

T is the tripping time in seconds

V is the positive sequence voltage in per unit

f is the positive sequence frequency in per unit

K is a parameter which raises or lowers the inverse time curve

Pickup is the user-settable minimum operating value of the V/f ratio

24DEF1 and 24DEF2 Definite Time Delay Overexcitation protection are similar to the 24INV except the operating time delay is definite. An application example of this function could be to trip a capacitor bank if its controller has failed.

Table 4.9: 24 Overexcitation Setting Functions

K	Factor for altering inverse time curve
Pickup	Minimum level that operates device 24INV
Reset Time	Time for 24INV to reset after element has dropped out
Pickup (24DEF)	Minimum level that operates device 24DEF1/24DEF2
Pickup Delay	Operating time for 24DEF

Table 4.10: 24 Overexcitation Setting Ranges	
24INV	Enable/Disable
K	0.10 to 100.00
Pickup (per unit)	1.00 to 2.00
Reset Time (seconds)	0.05 to 9999.99
24DEF1, 24DEF2	Enable/Disable
Pickup (per unit)	1.00 to 2.00
Pickup Delay (seconds)	0.05 to 9999.99

59N Zero Sequence Overvoltage

59N Zero Sequence Overvoltage protection is typically used to provide ground fault protection on ungrounded in high impedance grounded systems where neutral overcurrent protection cannot be used or does not have good sensitivity. The element operates on the residual voltage quantity $3V_0$.

The potential transformer source can be on either the HV or LV side of the transformer. The 59N uses standard IEC and IEEE curves as well as a user-defined curve type.

Pickup

$$T(3V_0) = TMS\left[B + \frac{A}{\left(\frac{3V_0}{3V_{0Pickup}}\right)^p - 1}\right] \quad (12)$$

Reset

$$T(3V_0) = TMS\left[\frac{TR}{1 - \left(\frac{3V_0}{3V_{0Pickup}}\right)^2}\right] \quad (13)$$

Table 4.11: IEC and IEEE Curves

No	Curve Type	A	B	p
1	IEC Standard Inverse	0.14 (fixed)	0.00 (fixed)	0.02 (fixed)
2	IEC Very Inverse	13.50 (fixed)	0.00 (fixed)	1.00 (fixed)
3	IEC Extremely Inverse	80.00 (fixed)	0.00 (fixed)	2.00 (fixed)
4	IEEE Moderately Inverse	0.0103(fixed)	0.0228 (fixed)	0.02 (fixed)
5	IEEE Very Inverse	3.922 (fixed)	0.0982 (fixed)	2.00 (fixed)
6	IEEE Extremely Inverse	5.64 (fixed)	0.0243 (fixed)	2.00 (fixed)
7	User-defined	[0.001, 1000]	[0.0, 10.0]	[0.01, 10.0]

Table 4.12: 59N Zero Sequence Overvoltage Setting Functions

$3V_0$ Pickup	Minimum level that operates device 59N
Curve Type	Sets the type of inverse time curve
TMS	Time scaling factor for inverse time curve
A, B, p	Parameters for defining the curve
TR	Factor for altering the reset time

Table 4.13: 59N Zero Sequence Overvoltage Setting Ranges

59N	Enable/disable
$3V_0$ Pickup (secondary volts)	5.00 TO 150.00
Curve Type	See Table 4.11: IEC and IEEE Curves on page 4-22
TMS	0.01 to 10.00
A	0.0010 to 1000.0
B	0.0000 to 10.0
P	0.01 to 10.00
TR	0.10 to 100.00

27 Undervoltage

Two sets of Undervoltage (27) elements are provided. When the voltage applied to the analog voltage inputs is below the 27 pickup level, the 27 will operate after its timer has expired.

The 27-1 and 27-2 functions are identical in terms of operating options. Use the Gate Switch setting to select the logical AND gate for 3-phase undervoltage function or use the logical OR gate for single-phase undervoltage.

When the gate switch is set to OR, then if any of A OR B OR C phase voltage drops below the pickup setting, the element will operate after the time delay.

When the gate switch is set to AND, then if A AND B AND C phase voltage drops below the pickup setting, the element will operate after the time delay.

The Pickup Delay timer is definite with a range of 0.00 second (i.e., instantaneous) to 99.99 seconds.

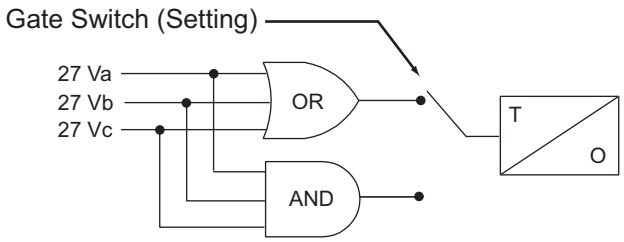


Figure 4.10: 27 Undervoltage

Table 4.14: 27 Undervoltage Setting Functions	
Pickup (volts)	Minimum level that operates device 27
Pickup Delay (seconds)	Operating time of the 27
Gate Switch	Allows either single-phase or three-phase operation

Table 4.15: 27 Undervoltage Setting Ranges	
27-1, 27-2	Enable/Disable
Gate Switch	AND or OR
Pickup (volts)	1.0 to 120.0
Pickup Delay (seconds)	0.00 to 99.99

59 Overvoltage

Two sets of Overvoltage (59) elements are provided. When the voltage applied to the analog voltage inputs is above the 59 pickup level, the 59 will operate after its timer has expired.

The 59-1 and 59-2 functions are identical in terms of operating options. Use the Gate Switch setting to select the logical AND gate for 3-Phase Overvoltage function, or select the logical OR gate for Single Phase Overvoltage.

When the gate switch is set to OR, then if any of A OR B OR C phase voltage rises above the pickup setting, the element will operate after the time delay.

When the gate switch is set to AND, then if A AND B AND C phase voltage rises above the pickup setting, the element will operate after the time delay.

The Pickup Delay timer is definite with a range of 0.00 second (i.e., instantaneous) to 99.99 seconds.

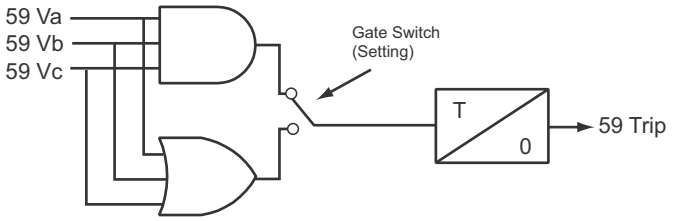


Figure 4.11: 59 Overvoltage

Table 4.16: 59 Overvoltage Setting Functions	
Pickup (volts)	Minimum level that operates device 59
Pickup Delay (seconds)	Operating time of the 59
Gate Switch	Allows either single-phase or three-phase operation

Table 4.17: 59 Overvoltage Setting Ranges	
59-1, 59-2	Enable/disable
Gate Switch	AND or OR
Pickup (volts)	1.0 to 138.0
Pickup Delay (seconds)	0.00 to 99.99

60 AC Loss of Potential

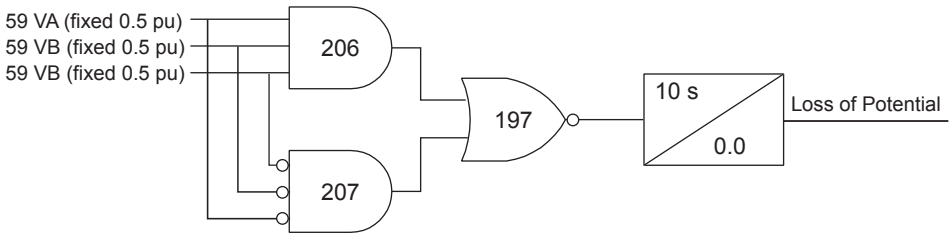


Figure 4.12: AC Loss of Potential Logic

AC Loss of Potential issues an alarm if it detects the loss of one or two phases of the PT voltage source. If the 60 is mapped to an output, an alarm or annunciation can be obtained. The delay is fixed at 10 seconds.

Table 4.18: 60 Loss of Potential Setting Ranges

60 Loss of Potential	Enable/disable
Pickup Time Delay	10 seconds (fixed)

81 Over/Under Frequency

The T-PRO has four frequency devices available. Each frequency element can be set to operate in the following modes:

- Fixed level of under-frequency
- Fixed level of over-frequency
- Specified rate of change level of frequency (df/dt)

The df/dt function can be set to operate for a positive rate of change or a negative rate of change.

Each frequency element has a definite time delay setting. All 81 elements shall be inhibited if the positive sequence voltage drops below the undervoltage supervision threshold, fixed at the greater of 0.25 per unit or 5 volts secondary.

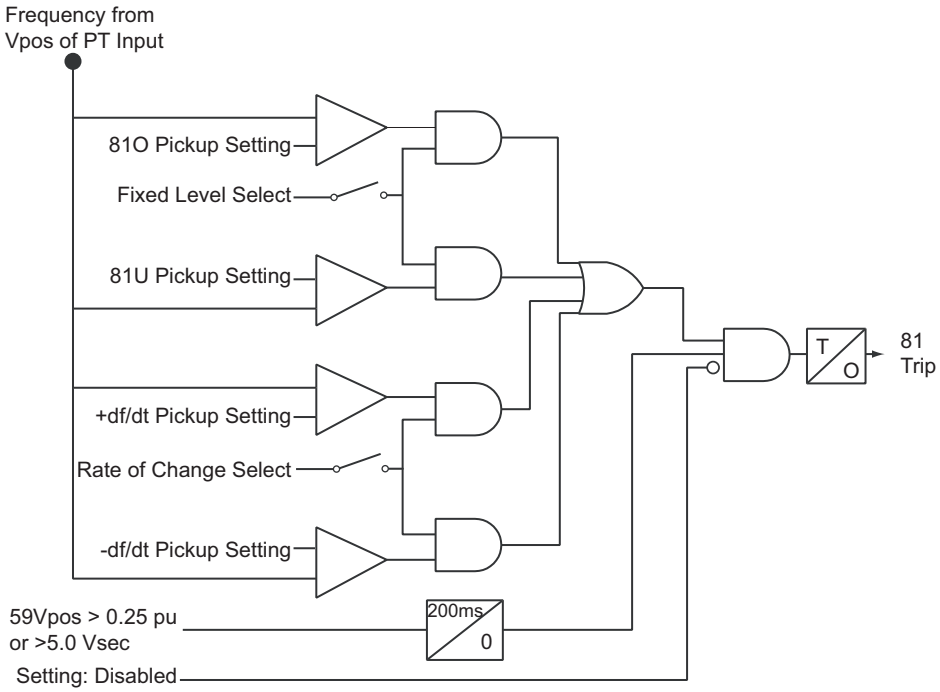


Figure 4.13: Over/Under Frequency Logic (One of Four Similar Elements Shown)

Table 4.19: 81 Frequency Setting Functions	
Pickup	Minimum level that operates device 81
Pickup Delay	Operating time for the 81

Table 4.20: 81 Frequency Setting Ranges	
81-1, 81-2, 81-3, 81-4	Enabled, disabled, fixed level, rate of change
Pickup (Hz/second) (60 Hz) Fixed Level	Between [50.000, 59.995] or [60.005, 70.000]
Pickup (Hz/second) (60 Hz) Rate of Change	Between [-10.0, -0.1] or [0.1, 10.0]
Pickup Delay (seconds) (60 Hz) Fixed Level	0.05 to 99.99
Pickup Delay (seconds) (60 Hz) Rate of Change	0.20 to 99.99
Pickup (Hz/second) (50 Hz) Fixed Level	Between [40.000, 49.995] or [50.005, 60.000]
Pickup (Hz/second) (50 Hz) Rate of Change	Between [-10.0, -0.1] or [0.1, 10.0]

Table 4.20: 81 Frequency Setting Ranges	
Pickup Delay (seconds) (50 Hz) Fixed Level	0.05 to 99.99
Pickup Delay (seconds) (50 Hz) Rate of Change	0.20 to 99.99

50/51 Overcurrent

Pickup

$$T(I) = TMS\left[B + \frac{A}{\left(\frac{I}{I_{Pickup}}\right)^{p} - 1}\right] \quad (14)$$

Reset

$$T(I) = TMS\left[\frac{TR}{1 - \left(\frac{I}{I_{Pickup}}\right)^{2}}\right] \quad (15)$$

There are non-directional Phase Time-Overcurrent (51) and Phase Instantaneous Overcurrent (50) elements available for each of the HV, LV and TV windings and they may be used in combination as required. The 50/51 provides backup to the primary 87 protection and should be coordinated with any downstream protection.

Depending on the associated CT connections, either the Wye current or the Delta Compensated Currents could be used in the 50/51 functions. When CTs on a winding are exclusively wye connected, the 50/51 will use the uncompensated currents (i.e., zero sequence will not be eliminated). However, if any of the winding's CTs are connected Delta then the Delta Compensated Currents are used. Delta Compensated Currents are described in the description of the 87 function on "87 Differential Protection" on page 4-1.

Each of the 51 functions are provided with 3 IEC inverse time curves, 3 IEEE inverse time curves, as well as 1 user-defined custom inverse time curve. Each winding's 51 operates on the per unit sum of all inputs assigned to the winding.

The input of each 50/51 is the maximum fundamental RMS current I_{max} among phases A, B and C. If I_{max} is greater than the pickup setting, an alarm is set and the relay starts to integrate towards a trip using the pickup formula. When the integrated torque reaches 1, a trip signal is issued.

The 51 reset is a back-integration process that will fully reset the 51 in a time determined by the reset formula.

Adaptive Feature

To automatically adjust the 51HV pickup level for different ambient temperature conditions, an adaptive feature is applied to device 51HV as in 51ADP Adaptive Overcurrent on "50/51 Overcurrent" on page 4-27.

The 50 device is an instantaneous or definite time overcurrent and operates when the I_{max} is above the pickup level for the duration of the set delay.

Note that the current used in the 50/51 functions may be the uncompensated Wye currents, or Delta Compensated currents. For more information, see "Note regarding delta compensated currents used in other T-PRO functions." on page 4-8.

Table 4.21: 50/51 Phase Overcurrent Setting Functions

50 Pickup	Minimum level that operates device 50
50 Pickup Delay	Operating time for the 50
51 Pickup	Minimum level that operates device 51
Curve Type	Sets the type of curve
TMS	Factor for altering inverse time curve
A, B, p	Parameters for defining the curve
TR	Factor for altering the reset time

Table 4.22: 50/51 Phase Overcurrent Setting Ranges

50	
HV, LV, TV	Enable/disable
Pickup (pu)	0.10 to 100.0
Pickup Delay (seconds)	0.00 to 99.99
51	
HV, LV, TV	Enable/disable
Pickup (pu)	0.05 to 5.00
Curve Type	See Table 4.11: IEC and IEEE Curves on page 4-22
Tms (Time Multiplier Setting)	0.01 to 10.00
A	0.0010 to 1000.0
B	0.0000 to 10.00
p	0.01 to 10.0
TR	0.10 to 100.00
51ADP	Enable/disable

Table 4.22: 50/51 Phase Overcurrent Setting Ranges	
Multiple of Normal LOL	0.5 to 512.0

51ADP Adaptive Overcurrent

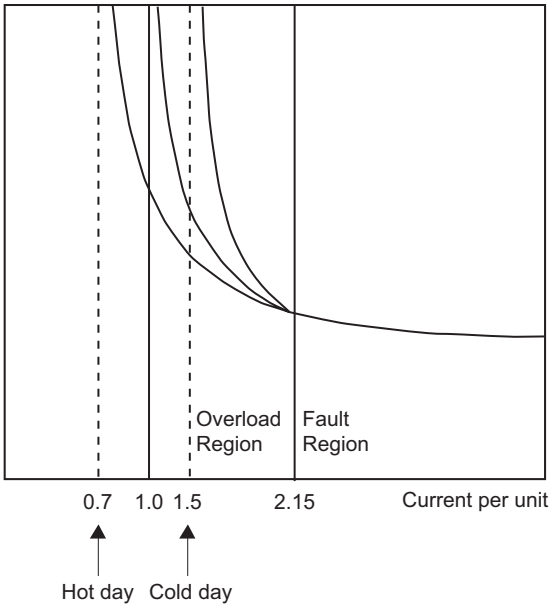


Figure 4.14: Ambient Temperature Adaptation

Ambient Temperature Adaptive Pickup (ADP) adjusts the pickup level of device 51HV based on the ambient temperature, a user-entered multiplier of normal loss of life and the equations defined in IEEE standard C57.92.1981. The adaptive function is executed at a rate of once per second.

If this function is enabled, the calculated adaptive pickup value becomes the device 51HV pickup setting. The 51ADP function re-shapes the inverse-time curve only in the overload region (up to 2.15 per unit), for details see Figure 4.14: Ambient Temperature Adaptation on page 29.

If the ambient temperature signal is out of range, the pickup of device 51HV reverts to the user-set non-adaptive value.

51ADP Adaptive Overcurrent - Cold Climates

When the ambient temperature input probe is connected, you can use the adaptive overcurrent function. If 51ADP function is enabled, the 51HV pickup is affected by the ambient temperature input and the rate of loss of life setting value. If this function is disabled, the 51HV pickup is not affected.

If rate of loss of life is set to one and ambient temperature is 30 Celsius, the pickup level of 51 will be 1.0 per unit. Use the curves in Example 1, “Loss of Life of Solid Insulation” in Appendix M to change the 30°C pickup level.

The alarm function of 51HV indicates when the pickup threshold has been exceeded.

Set the rate of loss of life value to 1.0. The pickup values can be affected over the range 0 < pickup < 2.15 per unit. No change in the overcurrent characteristic takes place above 2.15 times pickup. Since most fault coordination with other overcurrent relays occurs at fault levels above this value, coordination is not usually affected by the adaptive nature of the 51ADP function. However, check all specific applications.

If the ambient temperature input goes out of range with the adaptive function enabled, an alarm is generated. The event is logged and the overcurrent pickup reverts to the regular 51HV setting.

50N/51N Neutral Overcurrent

T-PRO provides 50N/51N neutral overcurrent protection for up to 3 neutral connected transformer windings. The functions use one of the following 3 Inputs of Input 5 as follows:

IN_{HV} to I5A

IN_{LV} to I5B

IN_{TV} to I5C

When 50N/51N functions are used, I5 cannot be used for the phase differential (87) function. If only one 50N/51N is required, the remaining I5 inputs may be used for fault recording from any CT source.

Neutral Overcurrent is similar to 50/51 except that the input currents are taken from the transformer neutral CTs and are set in the unit of secondary amps rather than per unit.

To enable 50N/51N, Current Input #5 must be set to 87N/51N or 87N Auto in Winding/CT Connections settings. If Input 5 is set to “87N Auto”, only 50N/51N-HV is available.

Table 4.23: 50N/51N Neutral Overcurrent Setting Functions

50N Pickup	Minimum level that operates device 50N
50N Pickup Delay	Operating time for the 50N
51N Pickup	Minimum level that operates device 51N
Curve Type	Sets the type of curve
TMS	Factor for altering inverse time curve
A, B, p	Parameters for defining the curve
TR	Factor for altering the reset time

Table 4.24: 50N/51N Neutral Overcurrent Setting Functions	
50N	
HV, LV, TV	Enable/disable
Pickup (A)	0.25 to 50.00 (5A) 0.05 to 10.00 (1A)
Pickup Delay (seconds)	0.00 to 99.99
51N	
HV, LV, TV	Enable/disable
Pickup (pu)	0.25 to 50.00 (5A) 0.05 to 10.00 (1A)
Curve Type	See Table 4.11: “IEC and IEEE Curves” on page 4-22
Tms (Time Multiplier Setting)	0.01 to 10.0
A	0.0010 to 1000.0
B	0.0000 to 10.00
p	0.01 to 10.0
TR	0.10 to 100.00

67 Directional Overcurrent

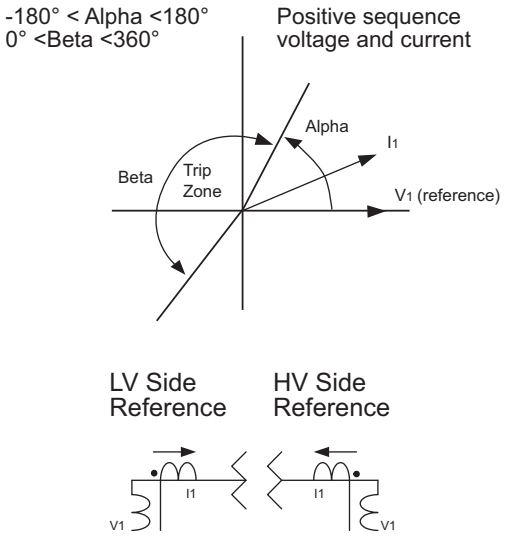


Figure 4.15: Directional Overcurrent Protection Characteristic

The 67 directional overcurrent function in T-PRO can be applied to either the HV or LV winding, whichever has the Potential Transformer connected to it. The 67 has a flexible directional characteristic that can be easily adapted to the desired directional application. For example, the 67 may be applied for directional fault detection (i.e., as in an Impedance domain), or it is commonly used to detect an abnormal operating condition where Watts and VARs are flowing in the undesired direction (i.e., as in a Power domain).

In the case of either domain, the 67 direction is defined by the difference between the Positive Sequence Voltage angle (we will call $V_{posangle}$) and the Positive Sequence Current angle (we will call $I_{posangle}$).

The current reference direction is always into the transformer on the side where the PT is connected.

The settings Alpha and Beta define the operating range of the 67 element and both represent the $I_{posangle}$ relative to the $V_{posangle}$ reference. For setting, consider $V_{posangle}$ to be a fixed reference at 0. The current operating range starts at the Alpha angle and ends at the Alpha + Beta angle.

For Directional Power Domain Considerations

The MW and MVAr operating range can be directly derived from angles covered by the Alpha to Alpha + Beta settings range. For the operating characteristic, see example in **Figure 4.15A** and note the power quadrants defining ±MW and ±MVAr.

For Impedance Domain Considerations

Although the Alpha and Beta settings are always set in the power domain, they can be set to cover an angle range in a desired impedance domain. In this case it's important to recognize that the impedance plane is the complex conjugate of the power domain since the Positive Sequence Impedance Angle $Z_{posangle} = V_{posangle} - I_{posangle}$. For an example, see Figure 4.16B: Same settings as Figure 4.16A, but phasors represented in the Impedance domain. on page 4-34 and note the impedance quadrants defining ±R and ±jX.

In terms of an impedance angle, the 67 Operating Range (in degrees) can be defined as:

$$(Z_{MTA} - (Beta)/2) \le 67 OperateZAngle \le (Z_{MTA} + (Beta)/2) \quad \text{(67Z)} \tag{16}$$

where:

ZMTA is the maximum torque angle, i.e., the positive sequence impedance angle in the center of the operating range

Beta is the Beta angle setting

67 Operate Z Angle is any angle in the operating range

Figure 4.16A: Alpha and Beta Setting example, phasors represented in the Power domain. on page 4-34 and Figure 4.16B: Same settings as Figure 4.16A, but phasors represented in the Impedance domain. on page 4-34, but phasors represented in the Impedance domain. represent the exact same Alpha and Beta settings but shows how those settings may be interpreted depending on whether you are considering the application from a Directional Power or Directional Impedance perspective.

In our example, refer to Figure 4.17: on page 4-37 and assume the PT is on LV side and we want the 67 to detect and trip for current flowing from the LV side towards the HV side for a HV Side fault.

Assume that from our fault study we found that we require a Z_{posang} MTA of +45 (i.e., current lag voltage by 45). Also assume that in our study, we found that a total operating range of 130 satisfies our requirements for all of the faults we need to detect. We use Equation 67Z to determine what our Alpha and Beta settings should be for our example:

$$(Z_{MTA} - (Beta)/2) \le 67 OperateZAngle \le (Z_{MTA} + (Beta)/2) \tag{17}$$

$$(45 - 130/2) \le 67 OperateZAngle \le (45 + 130/2)$$

$$(-20) \le 67 OperateZAngle \le 110$$

In this example we have found that we require $Z_{posangle}$ range between -20 to 110

Since the Alpha and Beta settings are for $I_{posangle}$ (remember V_{posang} is 0 reference):

$$I_{posang1} = V_{posang} - Z_{posang} = 0\text{-}20 = +20 \quad (18)$$

and

$$I_{posang2} = V_{posang} - Z_{posang} = 0\text{-}110 = -110 \quad (19)$$

Alpha setting is the smaller of the above two I_{posang} = -110 (i.e., -110 is smaller than +20).

The Beta setting is always the total desired operating range, in this example = 130.

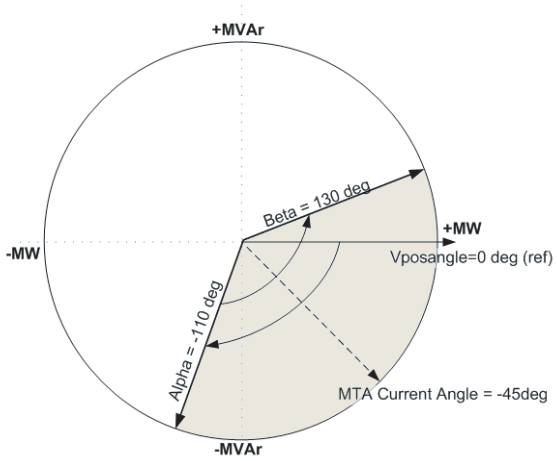


Figure 4.16A: Alpha and Beta Setting example, phasors represented in the Power domain.

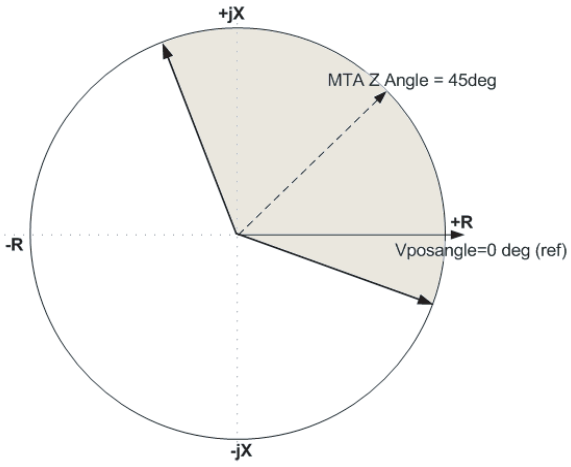


Figure 4.16B: Same settings as Figure 4.16A, but phasors represented in the Impedance domain.

General Setting Rules:

- Alpha cannot be < -179.99 and cannot be > 180,
- Beta cannot be <0.1 and cannot be >360
- Beta setting of 360 makes the 67 non-directional (i.e., omni-directional)

If the current is greater than the 67 pickup setting in any phase and the positive sequence current angle relative to the positive sequence voltage angle is within the Alpha and Beta operating range for the duration of the 67 time characteristic, then a trip output will be issued.

You can select an IEC, IEEE or user-defined inverse time characteristic of the function.

Note that the current used in the 67 function may be the uncompensated Wye currents or Delta Compensated currents, for details see Note regarding delta compensated currents used in other T-PRO functions. on page 4-8.

Table 4.25: 67 Directional Overcurrent Setting Functions

67 Pickup	Minimum level that operates device 67
Curve Type	Sets the type of curve
TMS	Factor for altering inverse time curve
A, B, p	Parameters for defining the curve
TR	Factor for altering the reset time
Alpha	Defines the starting angle for the trip region
Beta	Defines the size of the trip region in degrees offset from alpha

Table 4.26: 67 Directional Overcurrent Setting Ranges

67	Enable/disable
Curve Type	See Table 4.11: “IEC and IEEE Curves” on page 4-22
Pickup (pu)	0.05 to 5.00
TMS	0.01 to 10.00
A	0.001 to 1000.0
B	0.00 to 10.00
p	0.01 to 10.00
TR (seconds)	0.10 to 100.00
Alpha (degrees)	-179.9.0 to 180.0
Beta (degrees)	0.1 to 360.0

67N Directional Earth Fault

The 67N directional earth fault function in T-PRO can be also applied to either the HV or LV winding, whichever has the Potential Transformer connected to it. This function operates based on the same principle as the 67 directional overcurrent function, except the pickup level is based on the zero sequence current of the corresponding winding in Amps.

Table 4.27: 67N Directional Earth Fault Setting Functions

67N Pickup	Minimum level that operates device 67N
Curve Type	Sets the type of curve
TMS	Factor for altering inverse time curve
A, B, p	Parameters for defining the curve
TR	Factor for altering the reset time
Alpha	Defines the starting angle for the trip region
Beta	Defines the size of the trip region in degrees offset from alpha

Table 4.28: 67N Directional Earth Fault Setting Ranges

67N	Enable/disable
Curve Type	See Table 4.11: “IEC and IEEE Curves” on page 4-22
Pickup (A)	0.05 to 10.00 for 1 A 0.25 to 50.00 for 5 A
TMS	0.01 to 10.00
A	0.001 to 1000.0
B	0.00 to 10.00
p	0.01 to 10.00
TR (seconds)	0.10 to 100.00
Alpha (degrees)	-179.9.0 to 180.0
Beta (degrees)	0.1 to 360.0

50BF Breaker Fail

The T-PRO has a breaker fail function available for each of the 5 sets of current inputs. Each of the breaker fail functions are identical in design. The breaker fail function consists of the following parts:

- Initiating elements (selected in the Output Matrix screen).
- Overcurrent pickup level (if current detection is a selected method of detecting breaker fail).
- Breaker 52A contact (if breaker auxiliary contact position is a selected method of detecting breaker fail). 52A status can come from any of the External Inputs or any ProLogic statement.
- Time Delay 1 (typically used for re-trip attempt when its output is mapped to the breaker backup trip coil).
- Time Delay 2 (typically used to trip adjacent breakers in order to clear the fault).

Each of the 5 breaker fail element settings are independent of each other.

The Breaker Fail Initiate element for each breaker is determined by their association with the HV, LV or TV winding in the Winding/CT settings. For example if the breaker CT connected to Input 1 is from the HV transformer winding, then Input 1 50BF function will be initiated by any inputs mapped to BFI-HV column in the Output Matrix.

The 52A Breaker Status option, if used, looks for a 52A auxiliary contact status the assigned relay External Input. A 52B contact could be used but it must be converted to a 52A by inverting the status in ProLogic and then using the ProLogic output as the breaker 52A status.

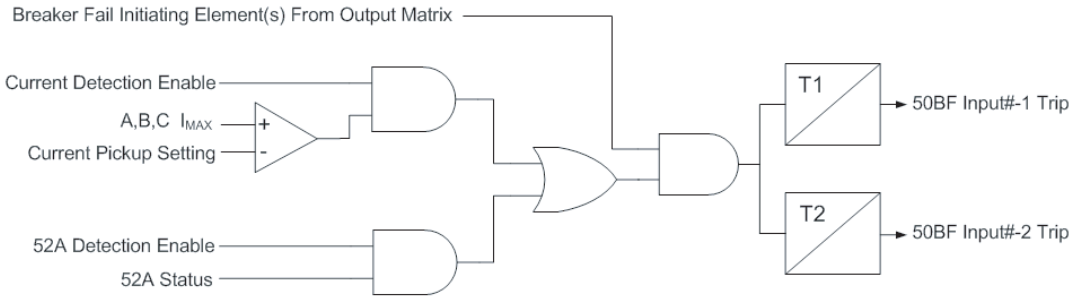


Figure 4.17: Breaker Fail Logic

Table 4.29: 50BF Breaker Fail Setting Functions	
Current Detection Enable	Enables breaker current detection functionality
Breaker Current Pickup	Minimum level that operates device 50BF
52A Breaker Status	Enables and selects input used for 52A status
Pickup Delay 1	Sets the delay of the breaker fail timer 1
Pickup Delay 2	Sets the delay of the breaker fail timer 2

Table 4.30: 50BF Breaker Fail Setting Ranges	
Current Detection Enable	Enable/Disable
Breaker Current Pickup	0.02 to 10.0 Amps (1 A) 0.10 to 50.0 Amps (5 A)
52A Breaker Status	Disable or Any External Input or Any ProLogic Statement
Pickup Delay 1	0.01 to 99.99 seconds
Pickup Delay 2	0.01 to 99.99 seconds

THD Alarm

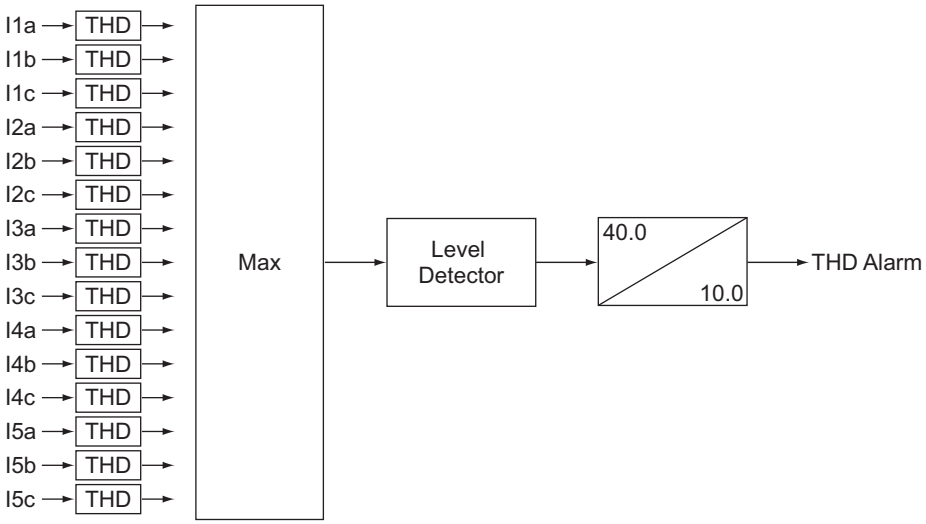


Figure 4.18: Total Harmonic Distortion Function

The THD Alarm function alerts you to the degree of current waveform distortion and therefore harmonic content.

For example, a THD setting of 10% means that the THD function operates if the total harmonic distortion exceeds 10% of the fundamental in any of the fundamental protection currents.

THD = 100% times the square root of the sum of the squares of the current harmonics (2nd – 25th) divided by the fundamental current value.

THD is defined as:

$$THD = \frac{\sqrt{\sum_{n=2}^{25} I_n^2}}{I_1} \times 100 \quad (20)$$

where:

I1 is the fundamental component

n=2 to n=25 are the harmonics components

The inputs to this function are the THD values of all the current input channels that are connected to the transformer. The channels that are not connected to the transformer (e.g. for recording only) or channels with low fundamental signals (less than 14% of nominal current) are not calculated for THD. The alarm is activated if the highest THD found exceeds the setting.

There is a built-in fixed time delay of from 30 – 40 seconds pickup and 1 – 10 seconds dropout to ensure that this is not a transient fault condition. The THD is executed in a slow rate, once per second. The THD values are calculated from the 96 samples buffer rather than the decimated 8 samples buffer because higher harmonics content (up to the 25th) can be included with 96 samples.

Table 4.31: Total Harmonic Distortion (THD) Alarm

THD Alarm	Enable/disable
Pickup (%)	5.0 to 100.0

Through Fault Monitor

The Through Fault Monitor function in T-PRO is used to analyze the thermal and mechanical effects of through faults on the transformer. The monitored quantities include the duration of each through fault, the current peak RMS value and the accumulated I^2t value of each phase during each through fault event. The total number of the through faults and the total accumulated I^2t values of each phase over the transformer life are also monitored.

The overall through fault monitor scheme is shown in the following figure.

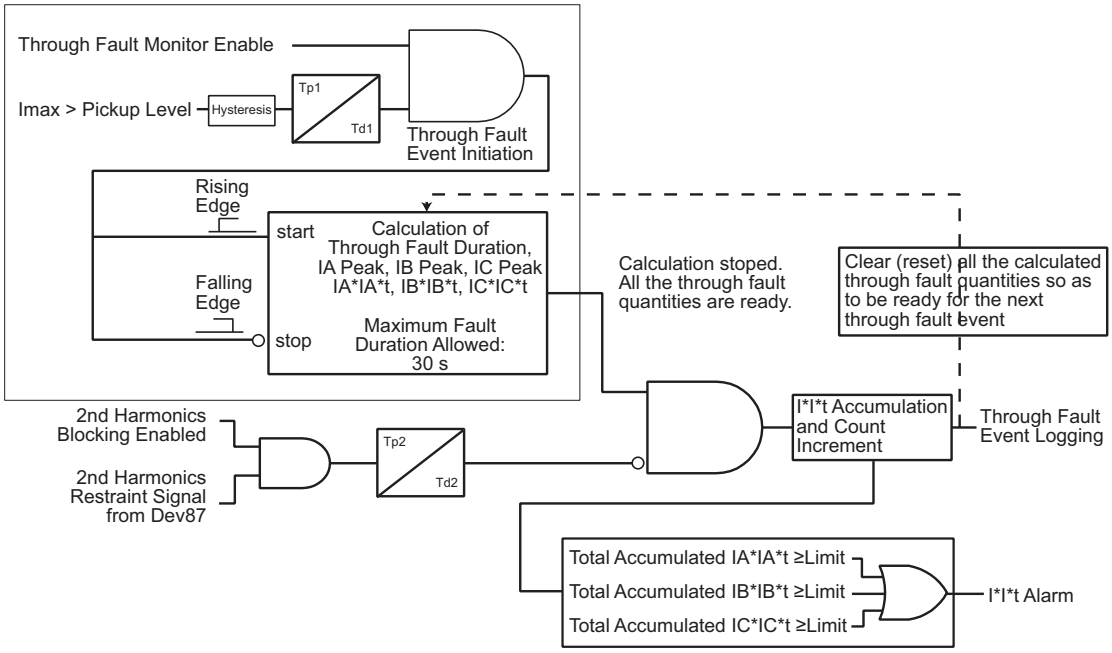

Through Fault Monitor Enable
Imax > Pickup Level
Hysteresis
Tp1
Td1
Through Fault Event Initiation
Rising Edge
Falling Edge
start
stop
Calculation of Through Fault Duration, IA Peak, IB Peak, IC Peak IA*IA*t, IB*IB*t, IC*IC*t
Maximum Fault Duration Allowed: 30 s
Calculation stoped. All the through fault quantities are ready.
Clear (reset) all the calculated through fault quantities so as to be ready for the next through fault event
2nd Harmonics Blocking Enabled
2nd Harmonics Restraint Signal from Dev87
Tp2
Td2
I*I*t Accumulation and Count Increment
Through Fault Event Logging
Total Accumulated IA*IA*t ≥Limit
Total Accumulated IB*IB*t ≥Limit
Total Accumulated IC*IC*t ≥Limit
I*I*t Alarm

Figure 4.19: Overall Through Fault Monitor Scheme

The through fault duration is defined as the time from when the input current Imax (the maximum current amongst phase A, B and C) exceeds the pickup threshold to when I_{max} drops below the pickup threshold - hysteresis. Note that the maximum allowed through fault duration is 30 seconds, this is to avoid the through fault event may never stop in case the pickup setting is set improperly so that the through fault event might be triggered under some load conditions. Pickup delay Tp1 and dropout delay Td1 are set to zero by default, however they can be set to other values based on the user's needs.

The2nd harmonic restraint logic output from device 87 is used to block the creation of through fault events on magnetizing inrush. The pickup and dropout timer (Tp2 and Td2) are used to distinguish between the 2nd harmonics caused by the fault transient and 2nd harmonics caused by transformer energization inrush. 2nd harmonics in the fault current only last for a very short period of time (e.g. 1 cycle or shorter) and 2nd harmonics in the inrush current last for quite a long time (e.g. a second or even longer). "2nd Harmonics Content in Fault Current" on page 4-41 shows an example of 2nd harmonics existing for a short time on load to fault transition.

Tp2 setting (default to 20ms) is used to ensure that the 2nd harmonic blocking will be only applied on the inrush current. Td2 setting is used to stretch the 2nd harmonics blocking signal once it picks up ensure that cannot reset too soon after the onset of inrush.

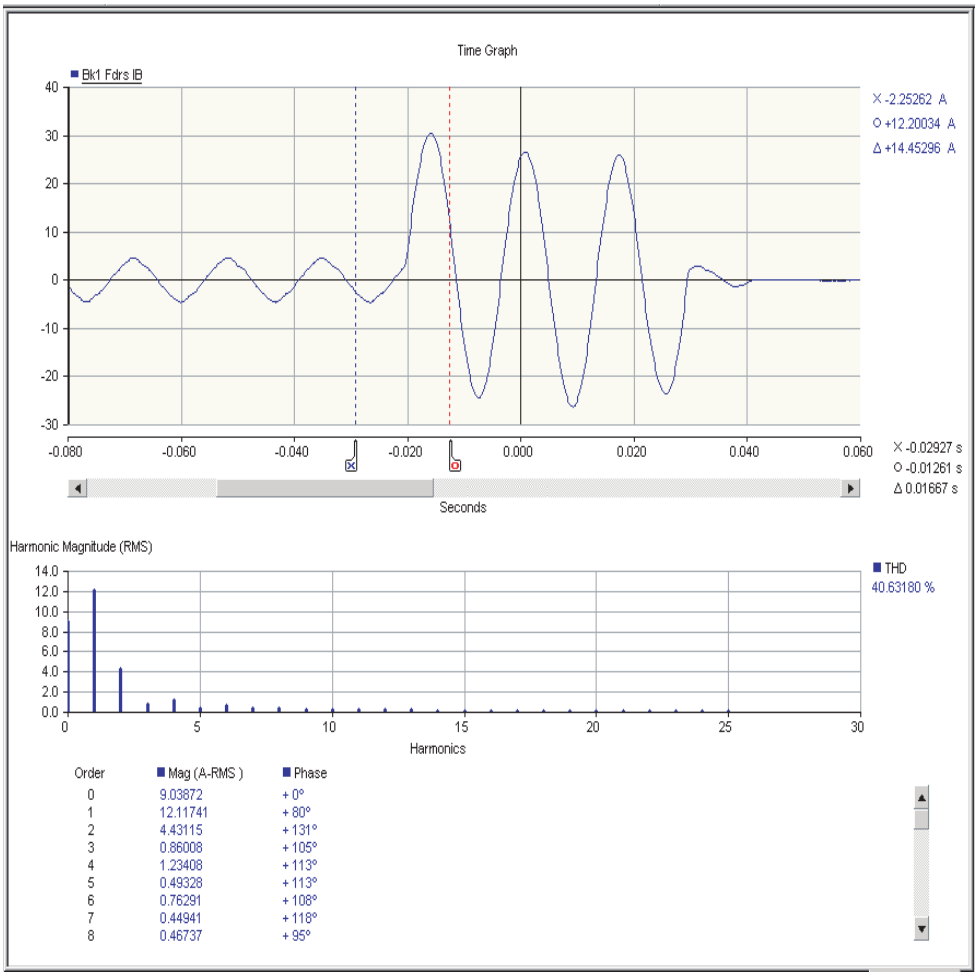


Figure 4.20: 2nd Harmonics Content in Fault Current

An alarm will be issued when the total accumulated I^2t value of any phase exceeds the preset threshold. When this occurs, some maintenance to the transformer should probably be scheduled. After that is completed, the total accumulated I^2t value should be reset. The I^2t alarm limit threshold may also need to be adjusted accordingly after successive accumulated I^2t values have been reached.

The through fault events and the associated monitored quantities can be viewed in the Event Log. The values are Through Fault Peak and Through Fault I*I*t" in Relay Control Panel. They can also be retrieved to RecordBase View and exported to MS Excel CSV format (refer to RecordBase View User Manual for

details). To avoid data loss of the through fault events, *Event Auto Save* feature in the *Record Length* settings should be enabled.

Table 4.32: Through Fault Monitor Setting Ranges

Through Fault Monitor	Enable/Disable
Input Current	HV, LV OR TV
Pickup Level (pu)	0.10 to 20.00
Hysteresis (pu)	0.00 to MIN (1.00, Pickup Level)
Pickup Delay (Tp1, seconds)	0.00 to 99.99
Dropout Delay (Td1, seconds)	0.00 to 99.99
I*I*t Alarm Limit (kA^2*s)	0.1 to 9999.9
2nd Harmonics Block	Enable/Disable
2nd Harmonics Block Pickup Timer (Tp2, seconds)	0.00 to 99.99
2nd Harmonics Dropout Timer (Td2, seconds)	0.00 to 99.99

4.1 ProLogic

ProLogic Control Statements

With ProLogic you can select any of the protection functions, External Inputs, Virtual Inputs, Output Contact status or any preceding ProLogic statements and place them into intuitive Boolean-like statements. Each ProLogic handles up to 5 functions to generate one ProLogic statement. Twenty four statements are possible per setting group. Each ProLogic has a pickup and dropout timer and a custom name field. The results from these statements can be mapped to output contacts or any of the eleven configurable front panel target LEDs in the output matrix.

The possible gates are AND, NAND, OR, NOR, XOR, XNOR, NXOR and LATCH.

The example shows A to E inputs are status points of devices that are user-selectable. Each ProLogic output can be given a specific name, pickup and reset time delay.

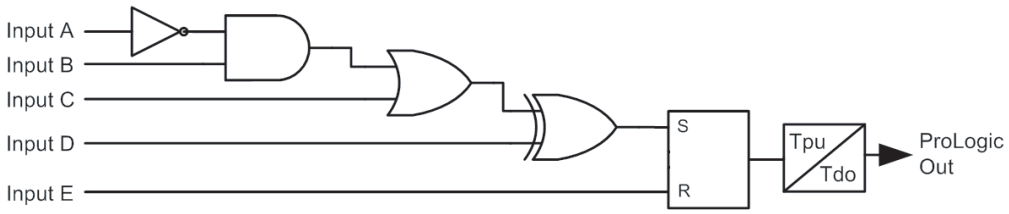


Figure 4.21: ProLogic Method

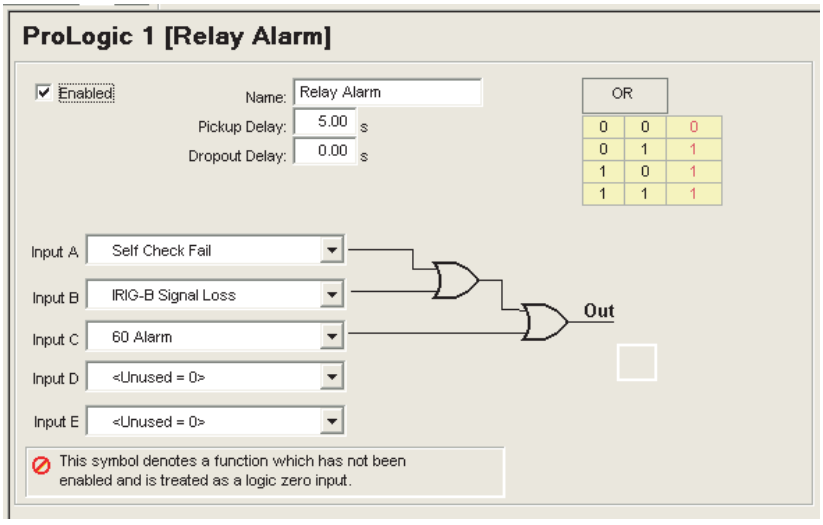


Figure 4.22: ProLogic Setting Screen

Table 4.33: ProLogic Setting Functions	
Name	Give the ProLogic a meaningful name.
Pickup Delay	Delay time from pickup to operate
Dropout Delay	Minimum time that the ProLogic will be active after it has operated.
A, B, C, D, E	Relay elements as input statements.
Operators	Boolean-type logic gates.

4.2 Group Logic

Each setting group has 16 Group Logic elements that can be used to switch setting groups based on the conditions you choose. The boolean logic method is similar to ProLogic. The input elements available are External Inputs, ProLogic Statements and Virtual Inputs.

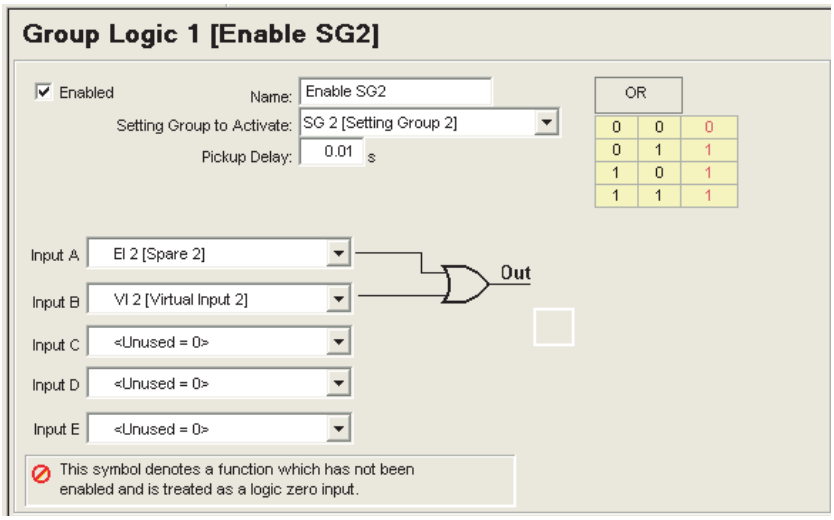


Figure 4.23: Group Logic Setting Screen

Table 4.34: Group Logic Setting Functions	
Name	Give the Group Logic a meaningful name.
Setting Group to Activate	Select which Setting Group should become active when your logic output goes high.
Pickup Delay	Time that the pickup must remain active to produce a function output.
A, B, C, D, E	Selection of External Inputs, ProLogic Outputs or Virtual Inputs as input statements.
Operators	Boolean-type logic gates.

4.3 Recording Functions

The T-PRO Relay provides numerous recording and logging functions, including a fault recorder, a trend log and an event log to analyze faults, to know the performance of the relay and to observe the status of the protected device.

Record Initiation

Recording can be initiated automatically by the relay when a fault or abnormal condition is detected. You can set the relay to initiate a fault recording on activation of any of its trip or alarm functions or on assertion of any external inputs or outputs. The assignment of fault record initiation to the various relay functions is done in the relay's Output Matrix settings.

A recording can also be initiated manually through the Relay Control Panel interface in the *Records* tab.

Record Storage

The T-PRO compresses records on the fly, achieving a typical lossless compression rate of 4:1. As a result, the T-PRO can store up to 150 seconds of fault recordings in non-volatile storage. If the storage is full, new records automatically overwrite the oldest, ensuring that the recording function is always available.

Record Retrieval and Deletion

A list of stored records is available through the Relay Control Panel in the *Records* tab. From Relay Control Panel you can retrieve the record and delete or leave on the relay, graph the record, export the record to COMTRADE.

Records are named by combining the Unit ID setting with the date and time of the initiating record trigger.

When transferred to your computer, the record name remains unchanged and the file extension indicates the record type: ".tpr" for transient recording, ".tpt" for a trend recording, ".tpe" for an event recording.

4.4 Fault Recorder

Fault recording captures the input signal waveforms and other derived quantities when a fault or an abnormal situation occurs. The relay determines this by allowing the user to select which functions in the Output Matrix should initiate a fault recording.

The quantities recorded are:

- 18 analog channels (3 voltages and 15 currents in secondary volts and amperes respectively), 96 samples/cycle up to the 25th harmonic
- 9 summation channels (3-phase HV, LV and TV currents), 96 samples/cycle up to the 25th harmonic
- 6 derived analog channels (3 operating currents, 3 restraint currents all are magnitude quantities in per unit), 8 samples/cycle. These derived and analog channels can be displayed on a Differential Trajectory graph).
- 9 or 20 external digital inputs, 96 samples/cycle
- 14 or 21 output contacts, 8 samples/cycle
- 30 Virtual Inputs, 8 samples/cycle
- 76 relay internal logic signals, 8 samples/cycle
- 24 ProLogic signals, 8 samples/cycle.

The recorded relay internal logic signals includes Phase segregated Start and Trip signals of Differential trip (87), Backup Over current (50/51), Backup Earth fault (50N/51N), Directional Over current (67), Directional Earth fault (67N), Over voltage (59) & Under voltage (27).

Parameters that are user-selectable with respect to recording faults are:

- Record length settable from 0.20 to 10.0 seconds including 0.10 to 2.00 seconds of Pre trigger.
- Recorder Triggering: By any internal logic or external input signal

4.5 Trend Recorder

The trend recorder provides continuous, slow-speed recording of the transformer and its characteristics with an adjustable sample period from 3 to 60 minutes per sample. This same global trend sampling rate is applied to all the trend quantities. The relay stores a fixed number of samples. At the nominal sample period of 3 minutes per sample T-PRO stores one month of trend records with automatic overwrite of the oldest. If the sample interval increases to 60 minutes per sample, the relay stores 600 days of trend records.

Table 4.35: Trend Recording

Sample Interval	Trend Record Length
3 minute	30 days
5 minute	50 days
10 minute	100 days
30 minute	300 days
60 minute	600 days

4.6 Event Log

The T-PRO maintains a log of events in a 250 entry circular log. Each entry contains the time of the event plus an event description. This log includes the time that the event took place and a predefined description of the event. Logged events include trips, alarms, external input assertions plus internal events such as setting changes. Trip and alarm protection events are logged only if these events have been user-programmed to initiate output relay closures or have been programmed to initiate fault recording in the Output Matrix of the settings.

Phase information is included in event messages where appropriate. For example, the event log entry for a device trip could be: “SubA-2011-08-18-15:34:19.832 – 87 Trip on ABC”.

The event log can be viewed in three ways:

- Relay Front HMI.
- Relay Control Panel interface is in the Events tab.
- SCADA protocols included in the T-PRO allow the SCADA master access to Trip and Alarm event data.

Events that occur during a transient fault recording are also embedded in the transient record and can be viewed in Relay Control Panel, RecordBase View and RecordGraph.

Although the event log is circular, you may ensure events are not lost by checking the *Event Auto Save* box in the Record Length setting screen of T-PRO Offliner. When this option is selected, as the event log approaches 250 events, it will save the records to an event file “.tpe”. The event log will then ready to capture up to 250 new events.

4.7 Fault Log

The T-PRO stores a log of faults in a 100 entry circular log. Each entry contains the time of the fault, fault type, faulted phase, fault quantities as per the below table. Fault log will be triggered only for trip condition and it won't log for an alarm condition.

Table 4.36: Fault Log

Fault Type	Fault Quantities
87 Phase Differential	- Io A/B/C Magnitudes - Ir A/B/C Magnitudes
87N HV, LV, TV Neutral Differential	- 3I0 Io Magnitude - 3I0 Ir Magnitude
24 Over excitation	- Voltage Positive Sequence Phasor (V1) - Frequency
59 Over voltage 27 Under voltage	- VA/VB/VC Phasors
50 HV, LV, TV Phase Overcurrent 51 HV, LV, TV Phase Overcurrent	- IA/IB/IC Phasors
67 Directional Phase Overcurrent	- VA/VB/VC Phasors - IA/IB/IC Phasors
50N HV, LV, TV Neutral Overcurrent 51N HV, LV, TV Neutral Overcurrent	- I5A Phasor (which is INhv) - I5B Phasor (which is INlv) - I5C Phasor (which is INtv)

The fault log can be viewed in three ways:

- Relay Front HMI.
- Relay Control Panel interface is in the Events tab.
- 61850 SCADA protocol included in the T-PRO allow the SCADA client access to Trip event data.

4.8 Output Matrix

The T-PRO Output Matrix is organized intuitively into a series of rows and columns. The rows contain all of the internal operating elements such as protection alarms, protection trips, ProLogic outputs, External Inputs, Virtual Inputs. The columns contain all of the output contacts, breaker fail initiates, recording triggers and target LED selections.

Selecting which row to connect to the column is a simple matter of placing your mouse cursor over the desired row and column intersection and clicking. The click of the mouse will toggle a green X on or off. If the X is present then the item is mapped. If there is no X then the item is not mapped.

The LEDs are selectable in the last column for each row. Use the drop-down list to select the desired LED to illuminate for the element that defines the row.

Functions that are disabled in the settings are shaded grey in the Output Matrix and cannot be selected.

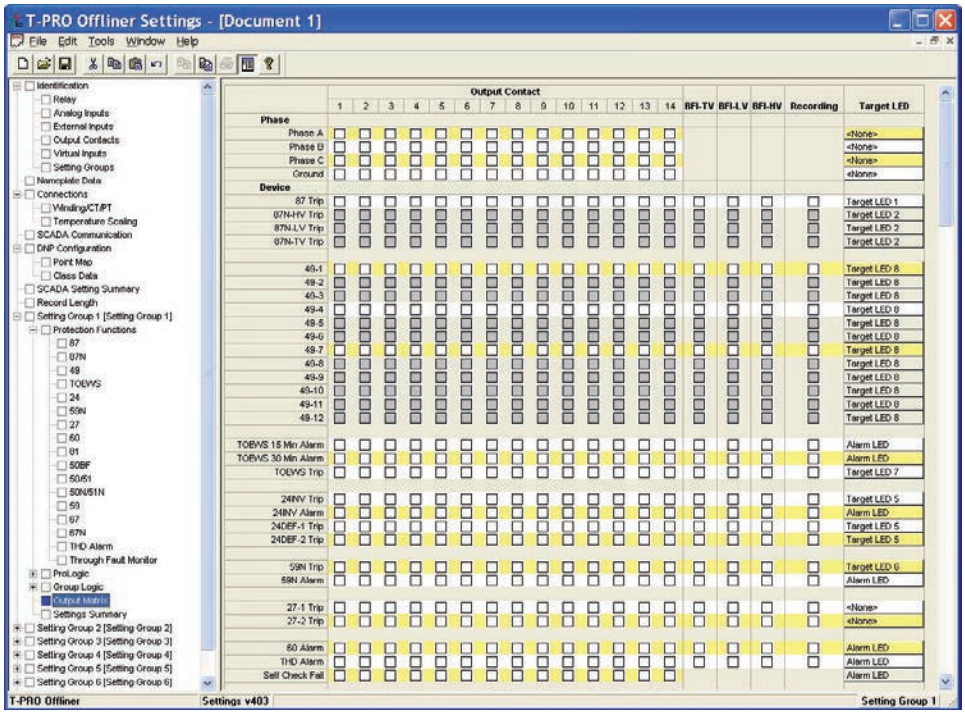


Figure 4.24: Output Matrix

5 Data Communications

5.1 Introduction

Section 5 deals with data communications with the T-PRO relay. First, the SCADA protocol is discussed, and it is then followed by the new IEC 61850 communication standard.

The SCADA protocol deals with the Modbus and DNP (Distributed Network Protocol) protocols. The SCADA configuration and its settings are described. The parameters for SCADA communications are defined using T-PRO 4000 Offliner software. Finally, details on how to monitor SCADA communications are given for maintenance and trouble shooting of the relay.

5.2 SCADA Protocol

Modbus Protocol

The relay supports either a Modbus RTU or Modbus ASCII SCADA connection. Modbus is available exclusively via a direct serial link.

Serial Modbus communications can be utilized exclusively via serial Port 122. Port 122 is an RS-232 DCE DB9F port located on the back of the relay. An external RS-232 to RS-485 converter can be used to connect the relay to an RS-485 network. For details on connecting to serial Port 122 see “Communicating with the T-PRO Relay ” on page 2-3 and “Communication Port Details” on page 2-20.

The data points available for Modbus SCADA interface are selectable by the user. Complete details regarding the Modbus protocol emulation and data point lists can be found in “Modbus RTU Communication Protocol” in Appendix E.

DNP Protocol

The relay supports a DNP3 (Level 2) SCADA connection. DNP3 is available via a direct serial link or an Ethernet LAN connection using either TCP or UDP.

Serial DNP communications can be utilized exclusively via serial Port 122. Port 122 is an RS-232 DCE DB9F port located on the back of the relay. An external RS-232 to RS-485 converter can be used to connect the relay to an RS-485 network. For details on connecting to serial Port 122, see “Communicating with the T-PRO Relay ” on page 2-3 and “Communication Port Details” on page 2-20.

Network DNP communications can be utilized via physical LAN Port 119 or Port 120. Port 119 is available as a RJ-45 port on the front of the relay and as an RJ-45 or ST fiber optic port on the rear. Port 120 located on the rear of the relay is available as an RJ-45 or ST fiber optic port. DNP communications can be used with multiple masters when it is utilized with TCP. For details on connecting to the Ethernet LAN, see “Network Link” on page 2-7.

The data points available for DNP SCADA interface are selectable by the user. Complete details regarding the DNP3 protocol emulation and data point lists can be found in “DNP3 Device Profile” in Appendix F.

SCADA Configuration and Settings

The parameters for SCADA communications may be defined using T-PRO 4000 Offliner.

If DNP3 LAN/WAN communications were chosen, the relay's network parameters need to be defined. This is done via the Maintenance interface. Note that this effort may already have been completed as part of the steps taken to establish a network maintenance connection to the relay. Establish a TUI session with the relay and log in as Maintenance. The following screen appears:

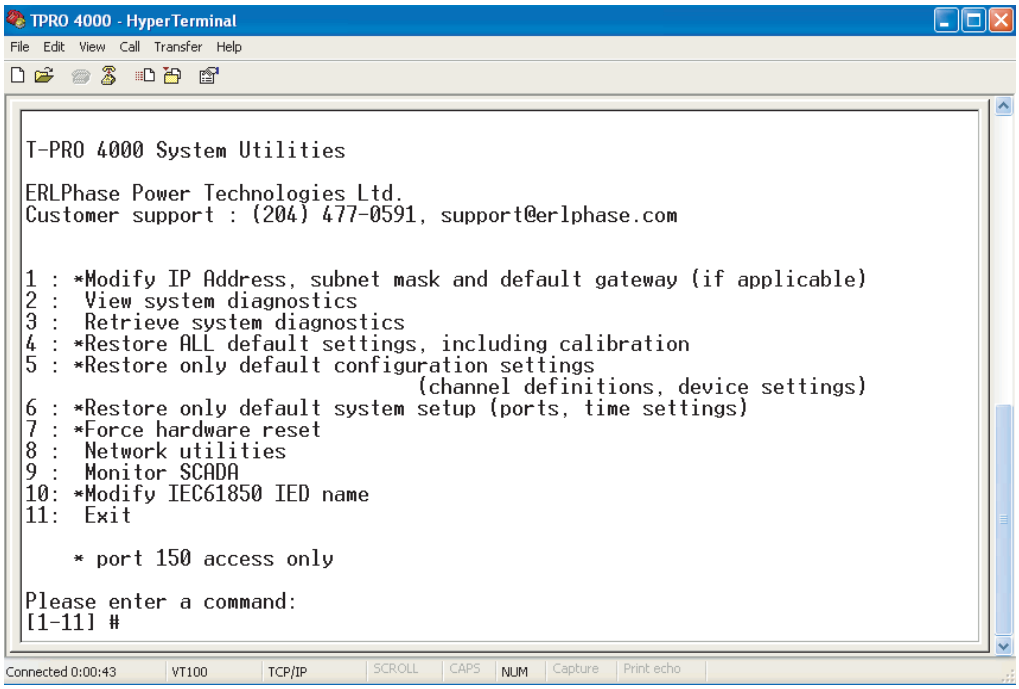

TPRO 4000 - HyperTerminal
File Edit View Call Transfer Help
T-PRO 4000 System Utilities
ERLPhase Power Technologies Ltd.
Customer support : (204) 477-0591, support@erlphase.com
1 : *Modify IP Address, subnet mask and default gateway (if applicable)
2 : View system diagnostics
3 : Retrieve system diagnostics
4 : *Restore ALL default settings, including calibration
5 : *Restore only default configuration settings
(channel definitions, device settings)
6 : *Restore only default system setup (ports, time settings)
7 : *Force hardware reset
8 : Network utilities
9 : Monitor SCADA
10: *Modify IEC61850 IED name
11: Exit
* port 150 access only
Please enter a command:
[1-11] #
Connected 0:00:43
VT100
TCP/IP
SCROLL
CAPS
NUM
Capture
Print echo

Figure 5.1: T-PRO 4000 System Utility

Select the first option by entering the number 1 followed by <Enter>. The following screen appears:

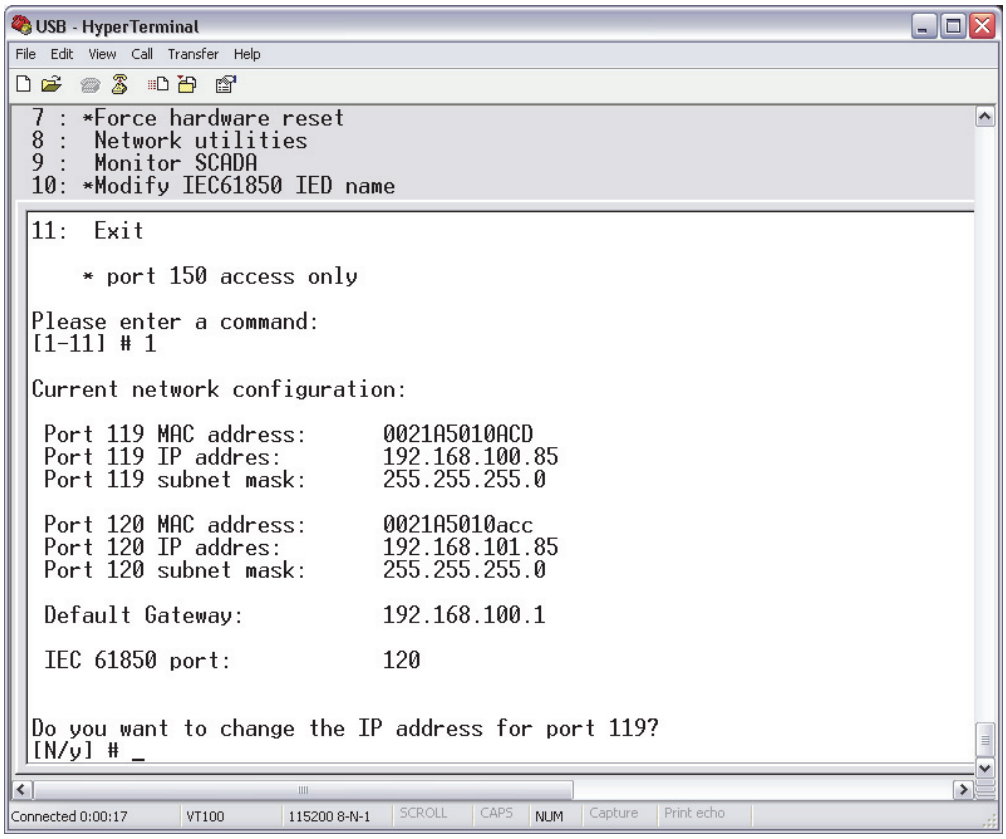


Figure 5.2: Change the network parameters as needed for the particular application

Offliner SCADA Configuration

Details on using the Offliner software are available in “Offliner Settings Software” on page 6-1. Details on downloading a completed settings file to the relay are available in “Sending a New Setting File to the Relay” on page 6-8.

Open the Offliner application per the instructions found in the indicated section and highlight the SCADA Communication selection. The screen appears as follows:

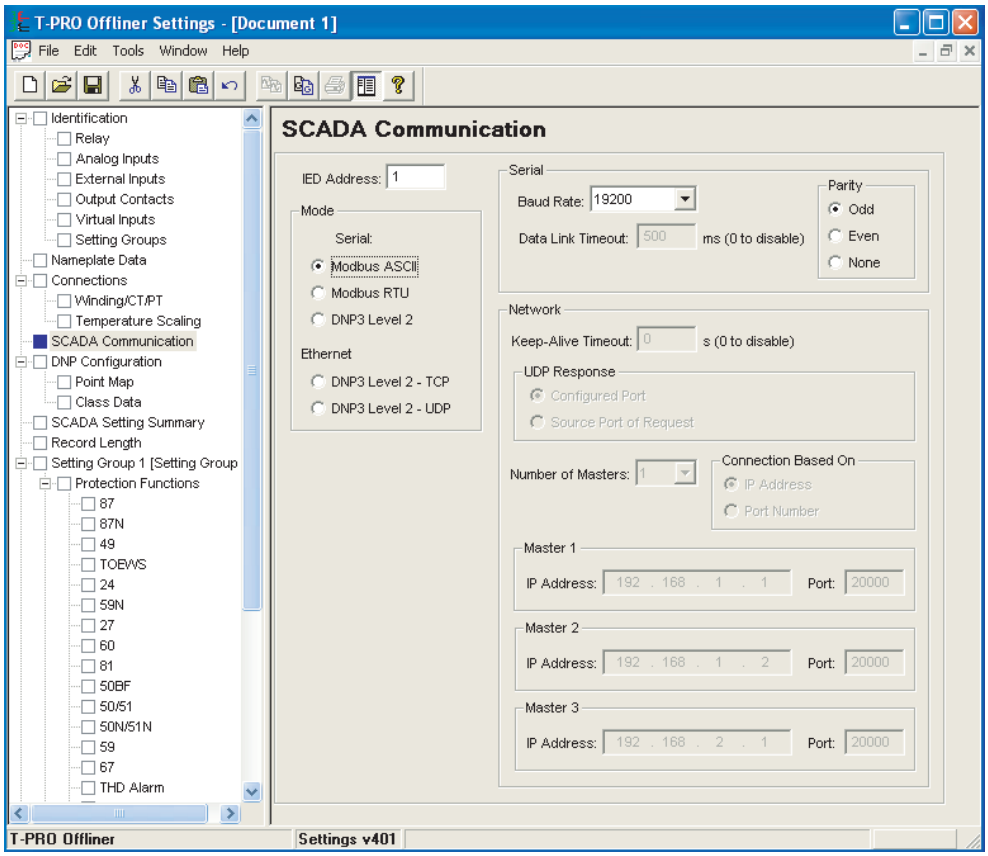


Figure 5.3: SCADA Communications

The configuration of SCADA communication parameters via the Offliner application is very intuitive. Several settings options are progressively visible and available depending on other selections. As noted before, there is no field to configure the number of data and stop bits. These values are fixed as follows:

- Modbus Serial - 7 data bits, 1 stop bit
- DNP Serial - 8 data bits, 1 stop bit

Monitoring SCADA Communications

The ability to monitor SCADA communications directly can be a valuable commissioning and troubleshooting tool. It can assist in resolving SCADA communication difficulties such as incompatible baud rate or addressing. The utility can be accessed through the Maintenance user interface, for details see “Maintenance Menu Commands” on page 2-15.

1. Establish a TUI session with the relay and log in as Maintenance.
2. Select the option 9 by entering the number **9** followed by *Enter*. The following screen appears:

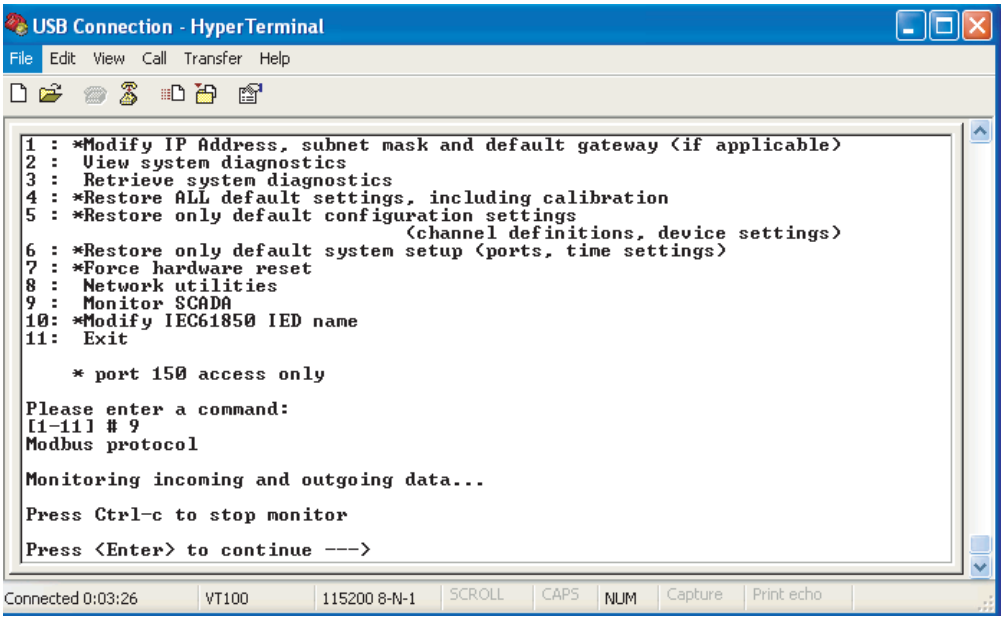

USB Connection - HyperTerminal
File Edit View Call Transfer Help
1 : *Modify IP Address, subnet mask and default gateway (if applicable)
2 : View system diagnostics
3 : Retrieve system diagnostics
4 : *Restore ALL default settings, including calibration
5 : *Restore only default configuration settings
(channel definitions, device settings)
6 : *Restore only default system setup (ports, time settings)
7 : *Force hardware reset
8 : Network utilities
9 : Monitor SCADA
10: *Modify IEC61850 IED name
11: Exit
* port 150 access only
Please enter a command:
[1-11] # 9
Modbus protocol
Monitoring incoming and outgoing data...
Press Ctrl-c to stop monitor
Press <Enter> to continue --->
Connected 0:03:26
VT100
115200 8-N-1
SCROLL
CAPS
NUM
Capture
Print echo

Figure 5.4: Login Screen

3. Pressing the *Enter* key results in all SCADA communications characters to be displayed as hexadecimal characters. Individual exchanges are separated by an asterisk as the following sample illustrates:

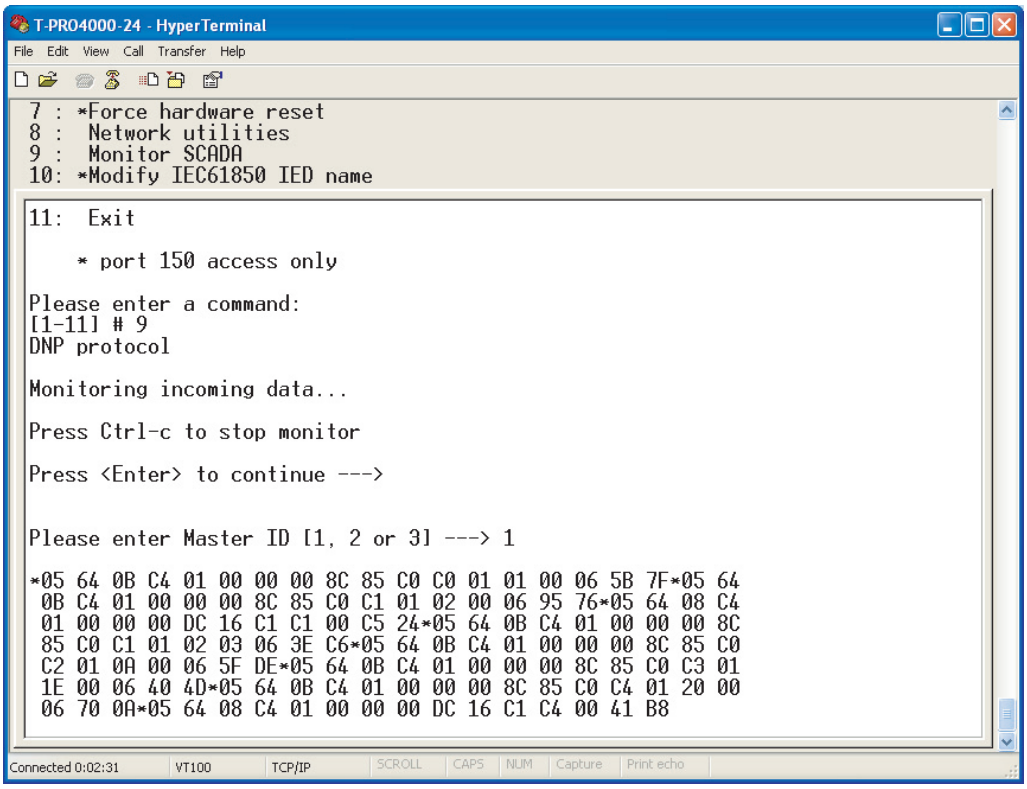

T-PRO4000-24 - HyperTerminal
File Edit View Call Transfer Help
7 : *Force hardware reset
8 : Network utilities
9 : Monitor SCADA
10: *Modify IEC61850 IED name
11: Exit
* port 150 access only
Please enter a command:
[1-11] # 9
DNP protocol
Monitoring incoming data...
Press Ctrl-c to stop monitor
Press <Enter> to continue --->
Please enter Master ID [1, 2 or 3] ---> 1
*05 64 0B C4 01 00 00 00 8C 85 C0 C0 01 01 00 06 5B 7F*05 64
0B C4 01 00 00 00 8C 85 C0 C1 01 02 00 06 95 76*05 64 08 C4
01 00 00 00 DC 16 C1 C1 00 C5 24*05 64 0B C4 01 00 00 00 8C
85 C0 C1 01 02 03 06 3E C6*05 64 0B C4 01 00 00 00 8C 85 C0
C2 01 0A 00 06 5F DE*05 64 0B C4 01 00 00 00 8C 85 C0 C3 01
1E 00 06 40 4D*05 64 0B C4 01 00 00 00 8C 85 C0 C4 01 20 00
06 70 0A*05 64 08 C4 01 00 00 00 DC 16 C1 C4 00 41 B8
Connected 0:02:31
VT100
TCP/IP
SCROLL
CAPS
NUM
Capture
Print echo

Figure 5.5: Hyperterminal

4. Press *Ctrl-C* to end the monitor session.

5.3 IEC61850 Communication

The IEC 61850 standard

The Smart Grid is transforming the electrical power industry by using digital technology to deliver electricity in a more intelligent, efficient and controlled way. Embedded control and communication devices are central to this transformation by adding intelligent automation to electrical networks.

The IEC 61850 standard defines a new protocol that permits substation equipment to communicate with each other. Like many other manufacturers, ERL-Phase Power Technologies is dedicated to using IEC 61850-based devices that can be used as part of an open and versatile communications network for substation automation.

The IEC 61850 defines an Ethernet-based protocol used in substations for data communication. Substations implement a number of controllers for protection, measurement, detection, alarms, and monitoring. System implementation is often slowed down by the fact that the controllers produced by different manufacturers are incompatible, since they do not support the same communication protocols. The problems associated with this incompatibility are quite serious, and result in increased costs for protocol integration and system maintenance.

Implementation Details

Implementation includes the following documents:

- Protocol Implementation Conformance Statement
- Model Implementation Conformance Statement
- Tissues Conformance Statement

All configurable IEC61850 parameters are available via the Maintenance interface. Note that this effort may already have been completed as part of the steps taken to establish a network maintenance connection to the relay.

1. Establish a TUI session with the relay and log in as **maintenance**. The following screen appears:

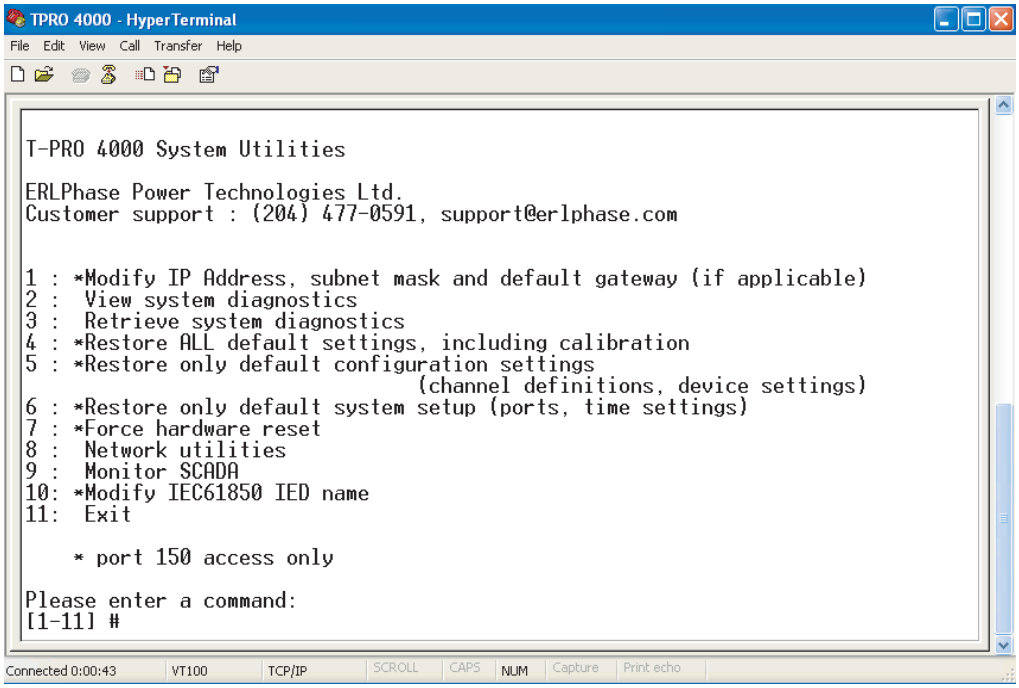

TPRO 4000 - HyperTerminal
File Edit View Call Transfer Help
T-PRO 4000 System Utilities
ERLPhase Power Technologies Ltd.
Customer support : (204) 477-0591, support@erlphase.com
1 : *Modify IP Address, subnet mask and default gateway (if applicable)
2 : View system diagnostics
3 : Retrieve system diagnostics
4 : *Restore ALL default settings, including calibration
5 : *Restore only default configuration settings
(channel definitions, device settings)
6 : *Restore only default system setup (ports, time settings)
7 : *Force hardware reset
8 : Network utilities
9 : Monitor SCADA
10: *Modify IEC61850 IED name
11: Exit
* port 150 access only
Please enter a command:
[1-11] #
Connected 0:00:43
VT100
TCP/IP
SCROLL
CAPS
NUM
Capture
Print echo

Figure 5.6: Maintenance Interface

2. Select the first option by entering the number **1** followed by *Enter*. The following screen appears:

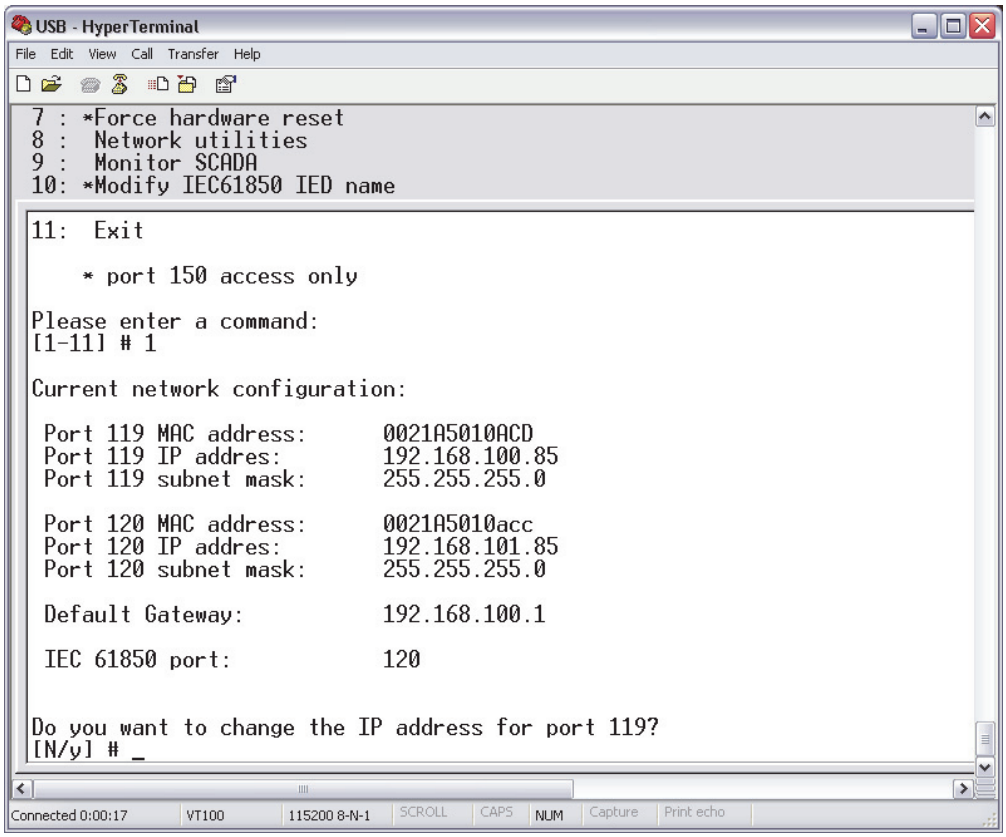


Figure 5.7: Change the network parameters as needed for the particular application

Note that unit's IP address can be used on the IEC61850 client side for unique unit identification instead of a physical device PD Name. The Publisher configuration is fixed and defined in the ICD file and available for reading to any IEC61850 client. Subscriber functionality is also fixed and supported for the Virtual Inputs only.

6 Offliner Settings Software

6.1 Introduction

This section deals with the Offliner Settings software. The Offliner settings software is used to create relay settings on a personal computer. Offliner provides an easy way to view and manipulate settings. Offliner supports all firmware versions and has the capability to convert older setting versions into newer ones.

In this section, first, the Offliner features are presented. The menu and toolbar are discussed and this is followed by a description of the Graphing and Protection functions.

Next, the Offliner features for handling backward compatibility with previous software versions is described. Also described are methods of converting a Settings File, sending a new Settings File to the relay and creating a Settings File from an older version of the software.

Next, the RecordBase View and RecordGraph to analyze the records from a relay are described.

This is followed by a lengthy description of the main branches from the Tree View. This section provides all information for Identification, System Parameters, SCADA Communication, DNP Configuration, SCADA Settings summary, Record Length, Setting Groups, ProLogic, Group Logic, Output Matrix and Settings summary.

Finally, a description of how the settings on the relay can be viewed through the RecordBase View analysis software is provided.

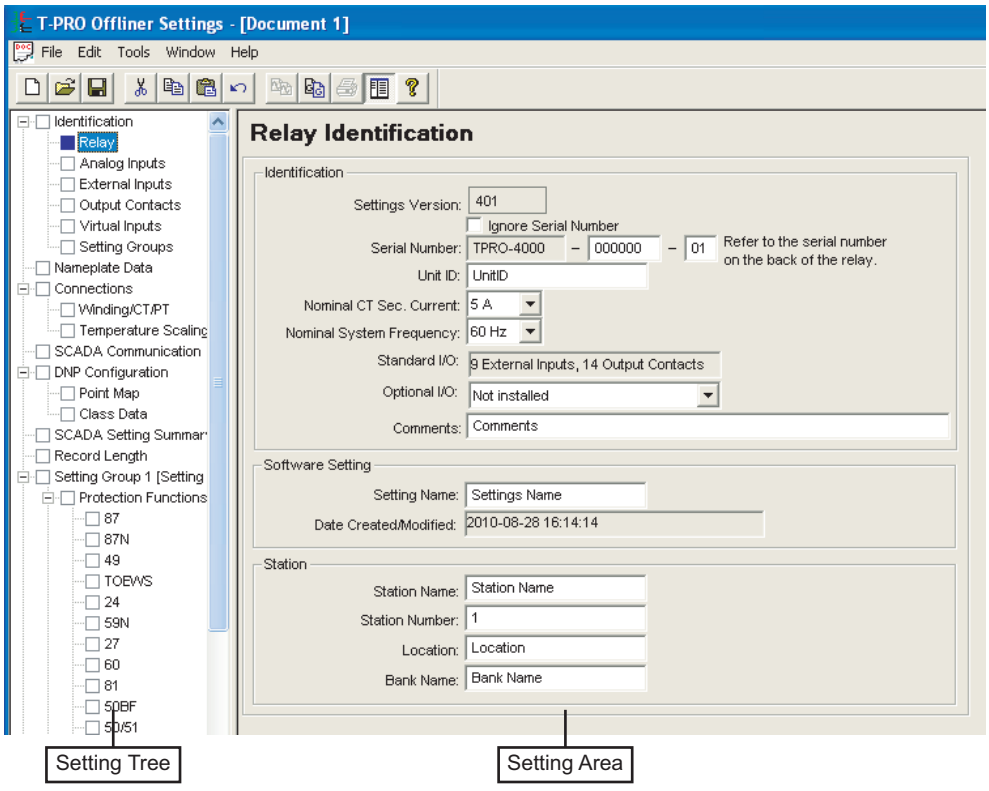


Figure 6.1: Opening Screen

6.2 Offliner Features

The Offliner software includes the following menu and system tool bar.

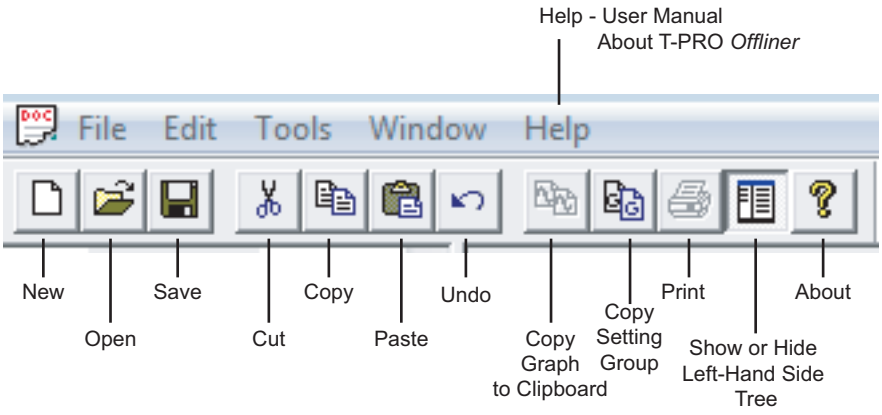


Figure 6.2: Top Tool Bar

Table 6.1: Windows Menu

Windows Menu	**Sub Menu**	**Comment**
Document Menu (Icon)	Restore	Restores active window to previous size
	Move	Allows user to move active window
	Size	Allows user to resize active window
	Minimize	Makes the active window as small as possible
	Maximize	Makes the active window as large as possible
	Close	Closes the active Offliner setting document
	Next	Switches to the next open Offliner setting file, if more than setting file is being edited

Table 6.1: Windows Menu		
File Menu	New	Opens up a default setting file of the most recent setting version
	Open	Open an existing setting file
	Close	Closes the active setting document
	Save	Saves the active setting file
	Save As	Saves the active setting file with a new name or location
	Convert to Newer	Convert an older setting version to a newer version.
	Print	Prints graphs or setting summary depending on active screen
	Print Preview	Provides a print preview of the setting summary
	Print Setup	Changes printers or print options
	1-8	The 8 most recently accessed setting files
	Exit	Quits the program
Edit Menu	Undo	Undo last action
	Cut	Cut the selection
	Copy	Copy the selection
	Paste	Insert clipboard contents
	Copy Graph	Copy the graph for the active screen to the clipboard
	Copy Setting Group	Copy values from one Setting Group to another
Tools	Options	Displays the Options Dialog Box
Window	Cascade	Cascades all open windows
	Tile	Tiles all open windows
	Hide/Show Tree	If this option is checked then the LHS Tree view will be hidden
	1-9, More Windows	Allows access to all open Offliner setting files. The active document will have a check beside it
Help	User Manual	Displays the user manual
	About Offliner	Displays the Offliner version
Toolbar		
New	Create a new document.	Create a new document of the most recent setting version
Open	Open an existing document.	Open an existing document

Table 6.1: Windows Menu		
Save	Save the active document.	Save the active document
Cut	Cut the selection.	Cut selection
Copy	Copy the selection.	Copy the selection
Paste	Insert clipboard contents.	Insert clipboard contents
Undo	Copy graph to clipboard.	Undo last action
Copy Graph		Copy the graph for the active screen to the clipboard
Copy Setting Group	Copy Setting Group	Copy values from one Setting Group to another
Show/Hide LHS Tree		If this option is checked then the LHS Tree view will be hidden
Print	Print active document.	Prints Graphs or the setting summary, depending on which seen is selected
About	Display program information.	Displays the Offliner version

6.3 Offliner Keyboard Shortcuts

The following table lists the keyboard shortcuts that Offliner provides.

Table 6.2: Keyboard Shortcuts	
Ctrl+N	Opens up a default setting file of the most recent setting version
Ctrl+O	Open an existing setting file
Ctrl+S	Saves the active setting file
Ctrl+Z	Undo
Ctrl+X	Cut
Ctrl+C	Copy
Ctrl+V	Paste
Ctrl+F4	Closes the active Offliner setting document
Ctrl+F6	Switches to the next open Offliner setting file, if more than one setting file is being edited
F6	Toggles between the LHS Tree view and HRS screen
F10, Alt	Enables menu keyboard short-cuts
F1	Displays the user manual

Graphing Protection Functions

Grid On/Grid Off

The graph of protection elements 87, 87N, all Overcurrents, 24, 59N can be viewed in Offliner with the grid on or off by toggling the Grid On or Grid Off button. A right-click on the trace of the curve gives the user the x and y coordinates.

Refresh

This button will refresh the graph to its default view if it has been zoomed.

Print Graph

To print a particular Offliner graph, click the *Print Graph* button.

Zoom on Graphs

Graphs can be zoomed to bring portions of the traces into clearer display. Left-click on the graph and drag to form a small box around the graph area. When the user releases the mouse, the trace assumes a new zoom position determined by the area of the zoom coordinates.

To undo the zoom on the graph, click the Refresh button.

Displaying Co-ordinates

At any time the user may right-click on the graph to display the co-ordinates of the point the user selected.

6.4 Handling Backward Compatibility

Offliner Settings displays the version number in the second pane on the bottom status bar. The settings version is a whole number (v3, v4,…v9, v10, v401, etc.). Settings up to v10 are for T-PRO 8700 model relay only; v401 and higher are for T-PRO 4000 model relays.

The Offliner Settings program is backward compatible. Open and edit older settings files and convert older settings files to a newer version for relays with upgraded firmware. Offliner Settings handles forward conversion only where you can convert an older version of settings to a newer version.

Converting a Settings File

1. Open the setting file you wish to convert.
2. In the *File* menu, select *Convert to...* and then select the *version x* (where x is the newer version). A dialog box pops up prompting the user for a new file name. You may use the same file name and overwrite the old, or you may enter a new file name. The conversion process inserts default values for any newly added devices in the new setting file. When the conversion is complete, Offliner Settings displays the new file.

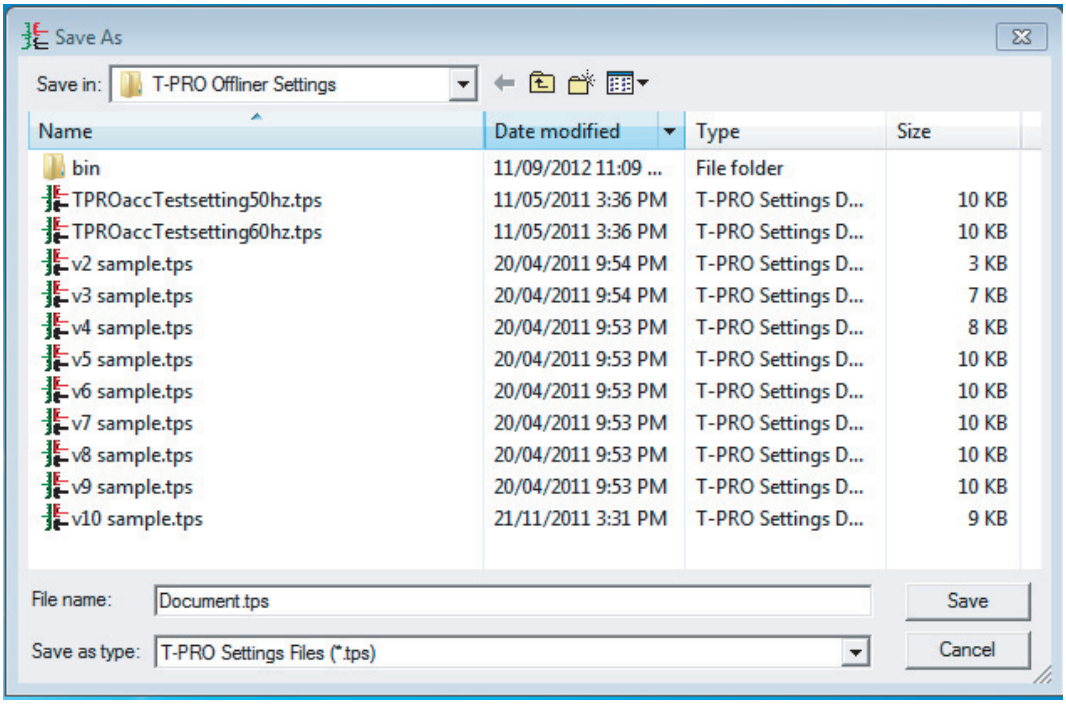


Figure 6.3: Converting Setting Files

Sending a New Setting File to the Relay

1. Make sure the settings version and the serial number of the relay in the setting file match. The relay will reject the setting file if either the serial number or the settings version do not match.

> A “serial number discrepancy” message may appear if the serial number of setting file does not match the serial number stored in the relay. This is to ensure the relay receives the intended settings. If this occurs, confirm the relay serial number that you can view in Relay Control Panel matches the serial number in the Offliner Identification Serial No. box. Alternately you may check the Ignore Serial Number check box to bypass serial number supervision.

2. Check the serial number and the settings version of the relay. The Device Serial Number and Required Settings Version on the Identification screen indicate the serial number and the settings version of the relay.

Creating a Setting File from an Older Version

1. Offliner Settings displays a default setting file on start up which shows the settings version in the bottom status bar. As an example T-PRO Offliner is shipped with a set of default sample files of older settings versions. These sample files are “v2 sample.tps”, “v3 sample.tps”, etc.

   Each sample file contains default values of an older settings version. For a new installation these sample files are placed in the default directory C:\Program Files\ERLPhase\T-PRO Offliner Settings, or you can choose the path during the Offliner software installation.

   If an older version of T-PRO Offliner was previously installed on your PC, then the default directory may be C:\Program Files\NxtPhase\T-PRO Offliner Settings, or C:\Program Files\APT\T-PRO Offliner Settings.
2. Open a sample file of the desired version. Use *File/Save As* to save the sample file to a new file name and path. Then edit the setting file and the serial number, save it and load it into the relay.

6.5 Main Branches from the Tree View

Identification

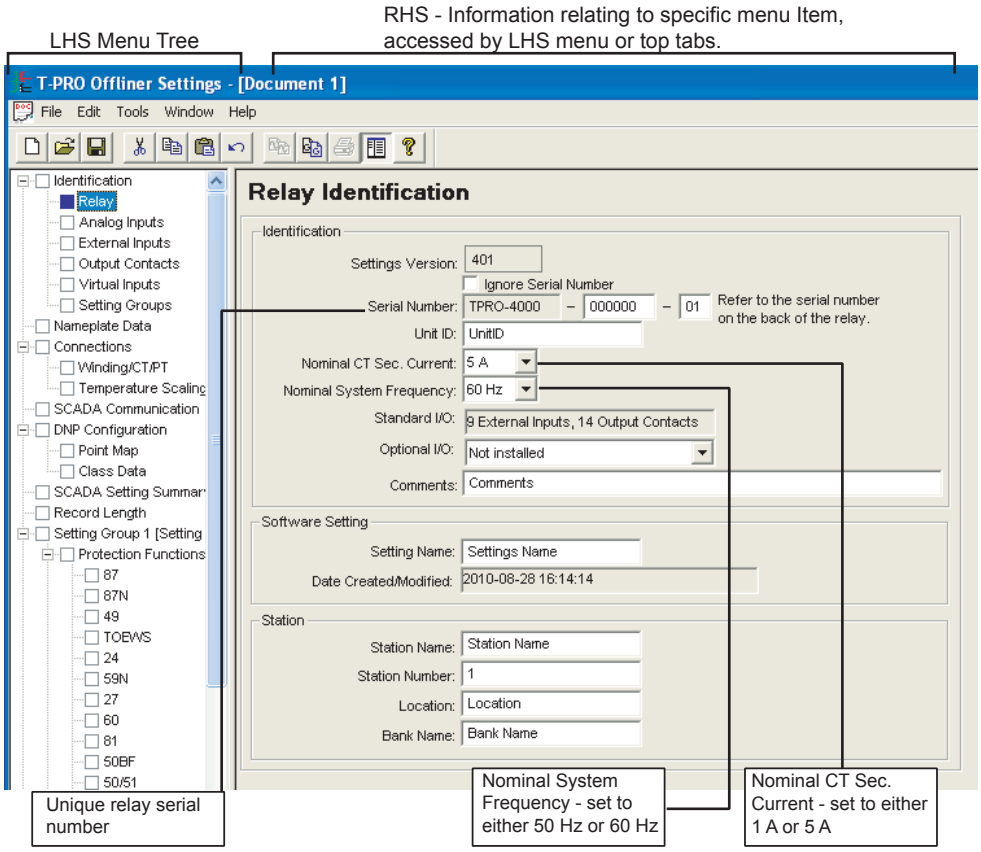


Figure 6.4: Relay Identification

The first screen presents all the menu items in the left menu tree. You can access the menu items by clicking the tabs at the top of the screen or the item on the left menu tree.

Table 6.3: Identification	
Identification	
Settings Version	Indicates the settings version number, fixed.
Ignore Serial Number	Bypass serial number check, if enabled.
Serial Number	Available at back of each relay.
Unit ID	User-defined up to 20 characters.
Nominal CT Sec. Current	5 A or 1 A
Nominal System Frequency	60 Hz or 50 Hz

Table 6.3: Identification	
Standard I/O	9 External Inputs, 14 Output Contacts
Optional I/O	9Not Installed or 11 External Inputs, 7 Output Contacts
Comments	User-defined up to 78 characters.
Setting Software	
Setting Name	User-defined up to 20 characters.
Date Created/Modified	Indicates the last time settings were entered.
Station	
Station Name	User-defined up to 20 characters.
Station Number	User-defined up to 20 characters.
Location	User-defined up to 20 characters.
Bank Name	User-defined up to 20 characters.

Important Note

Nominal CT Sec. Current can be set to either 1 A or 5 A.

Nominal System Frequency can be set to either 50 Hz or 60 Hz.

Ensure setting file selection matches that of target T-PRO.

The serial number of the relay must match the one in the setting file, or the setting will be rejected by the relay. This feature ensures that the correct setting file is applied to the right relay.

You can choose to ignore the serial number enforcement in the identification screen. The relay only checks for proper relay type and setting version if the ignore serial number has been chosen.

Analog Inputs

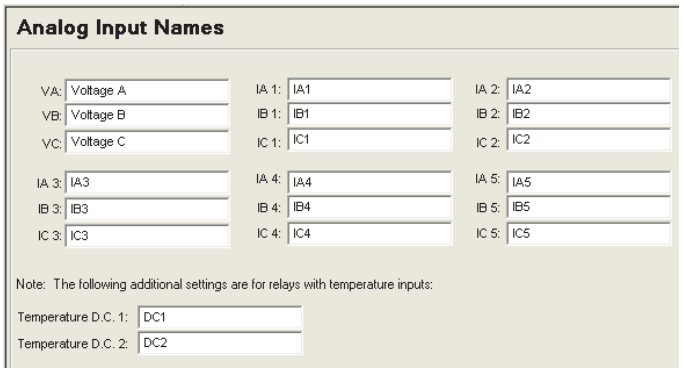


Figure 6.5: Analog Inputs

Identify all AC voltage and current inputs to the relay. These names appear in any fault disturbance records the relay produces.

Table 6.4: Analog Input Names

Voltage Inputs	VA, VB, VC
Current Inputs	IA1, IB1, IC1
	IA2, IB2, IC2
	IA3, IB3, IC3
	IA4, IB4, IC4
	IA5, IB5, IC5
Temp Inputs	Temp 1, Temp 2

External Inputs

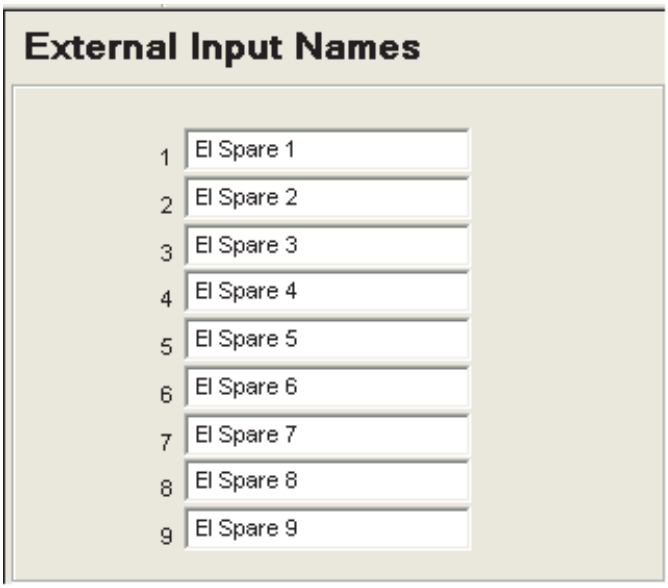


Figure 6.6: External Inputs

Define meaningful names for the external digital inputs.

Table 6.5: External Input Names	
1 to 9 And Optional 10 to 20	User-defined

Output Contacts

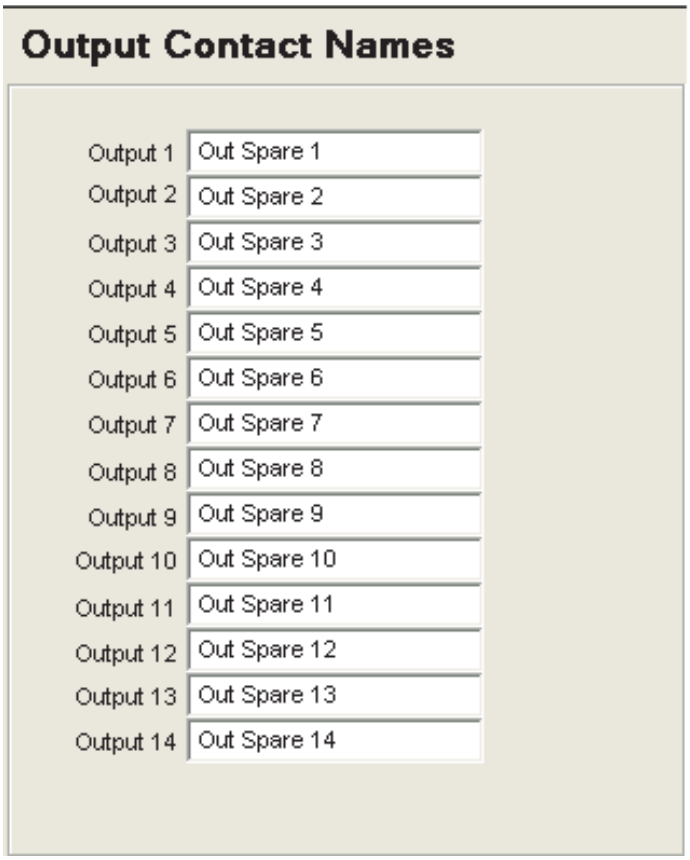


Figure 6.7: Output Contacts

Define meaningful names for the output contacts.

Table 6.6: Output Contact Names	
Outputs 1 to 14 And Optional 15 to 21	User-defined

Virtual Inputs

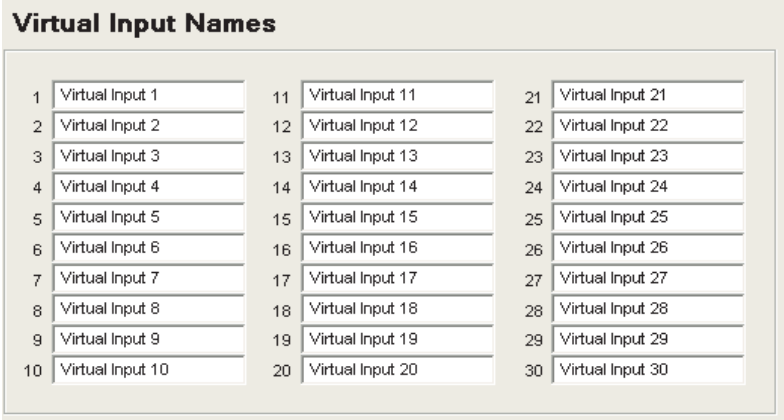

Virtual Input Names
1 Virtual Input 1
2 Virtual Input 2
3 Virtual Input 3
4 Virtual Input 4
5 Virtual Input 5
6 Virtual Input 6
7 Virtual Input 7
8 Virtual Input 8
9 Virtual Input 9
10 Virtual Input 10
11 Virtual Input 11
12 Virtual Input 12
13 Virtual Input 13
14 Virtual Input 14
15 Virtual Input 15
16 Virtual Input 16
17 Virtual Input 17
18 Virtual Input 18
19 Virtual Input 19
20 Virtual Input 20
21 Virtual Input 21
22 Virtual Input 22
23 Virtual Input 23
24 Virtual Input 24
25 Virtual Input 25
26 Virtual Input 26
27 Virtual Input 27
28 Virtual Input 28
29 Virtual Input 29
30 Virtual Input 30

Figure 6.8: Virtual Inputs

Define meaningful names for the virtual inputs.

Table 6.7: Virtual Input Names	
Inputs 1 to 30	User-defined

Setting Groups

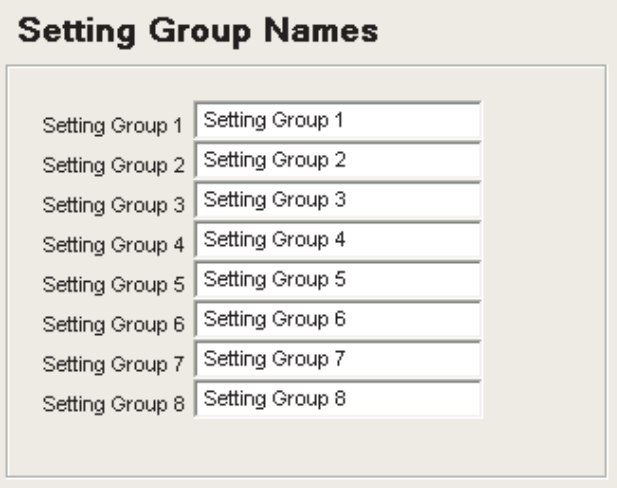


Figure 6.9: Setting Group Names

Define meaningful names for the setting groups.

Table 6.8: Setting Group Names	
Setting Groups 1 to 8	User-defined

Nameplate Data

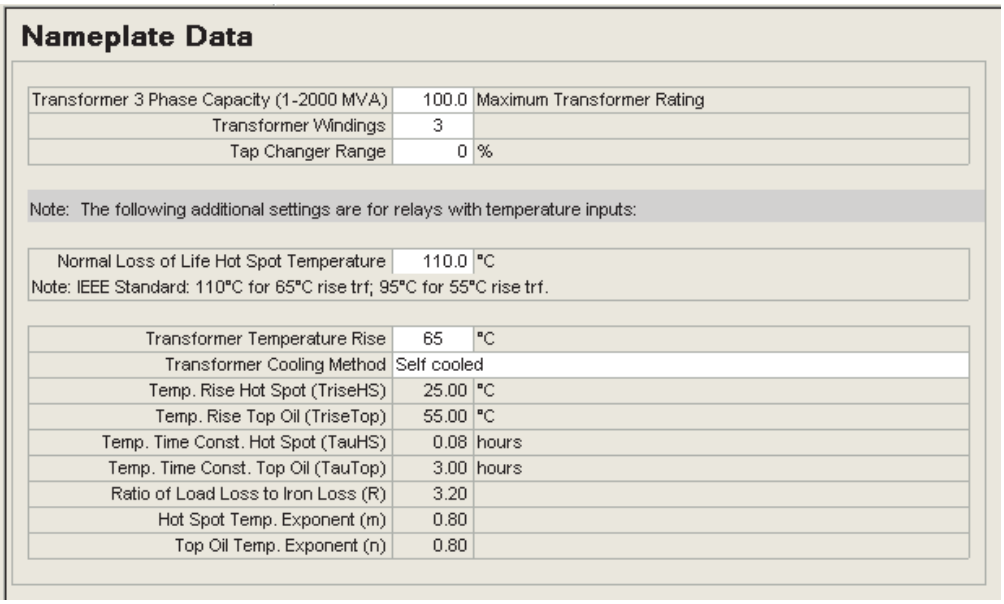

Nameplate Data
Transformer 3 Phase Capacity (1-2000 MVA) 100.0 Maximum Transformer Rating
Transformer Windings 3
Tap Changer Range 0 %
Note: The following additional settings are for relays with temperature inputs:
Normal Loss of Life Hot Spot Temperature 110.0 °C
Note: IEEE Standard: 110°C for 65°C rise trf; 95°C for 55°C rise trf.
Transformer Temperature Rise 65 °C
Transformer Cooling Method Self cooled
Temp. Rise Hot Spot (TriseHS) 25.00 °C
Temp. Rise Top Oil (TriseTop) 55.00 °C
Temp. Time Const. Hot Spot (TauHS) 0.08 hours
Temp. Time Const. Top Oil (TauTop) 3.00 hours
Ratio of Load Loss to Iron Loss (R) 3.20
Hot Spot Temp. Exponent (m) 0.80
Top Oil Temp. Exponent (n) 0.80

Figure 6.10: Nameplate Data

The transformer in the example of Figure 6.10: Nameplate Data on page 6-16 has a maximum rating of 100 MVA, and that value becomes the per unit base quantity for the relay. Any reference to “per unit” in the settings is related to the Base MVA.

The temperature rise value and the cooling method provided form the basis for loss of life calculations of the transformer. When “User-Defined” is selected as transformer cooling method, the seven transformer temperature parameters become editable.

If you select other cooling methods, these parameters are no longer editable, and the default values based on IEEE standards are used for the transformer temperature calculation.

Table 6.9: Nameplate Data	
Transformer 3-phase Capacity (MVA)	1 to 2000
Transformer Windings	2 or 3
Tap Changer Range (percent)	-100 to 100
Normal Loss of Life Hot Spot Temperature (degrees)	70.0 to 200.0
Transformer Temperature Rise (degrees)	55 or 65

Table 6.9: Nameplate Data	
Transformer Cooling Method	Self-cooled Forced air cooled, (ONAN/ONAF) rated 133% or less of self cooled rating Forced air cooled, directed flow (ODAF, ODWF, ONAN /ODAF/ODAF) Forced air cooled, (ONAN/ONAF/ONAF) rated over 133% of self-cooled rating Forced air cooled, non-directed flow (OFAF/ OFWF, ONAN /OFAF /OFAF) User-defined
Temp. Rise Hot Spot (TriseHS) (degrees)	10 to 110
Temp. Rise Top Oil (TriseTop) (degrees)	10 to 110
Temp. Time Const. Hot Spot (TauHS) (hours)	0.01 to 2.00
Temp. Time Const. Top Oil (TauTop) (hours)	0.02 to 20.00
Ratio of Load Loss to Iron Loss (R)	0.50 to 10.00
Hot Spot Temp. Exponent (m)	0.50 to 2.00
Top Oil Temp. Exponent (n)	0.50 to 2.00

Connections

Windings/CT Connections

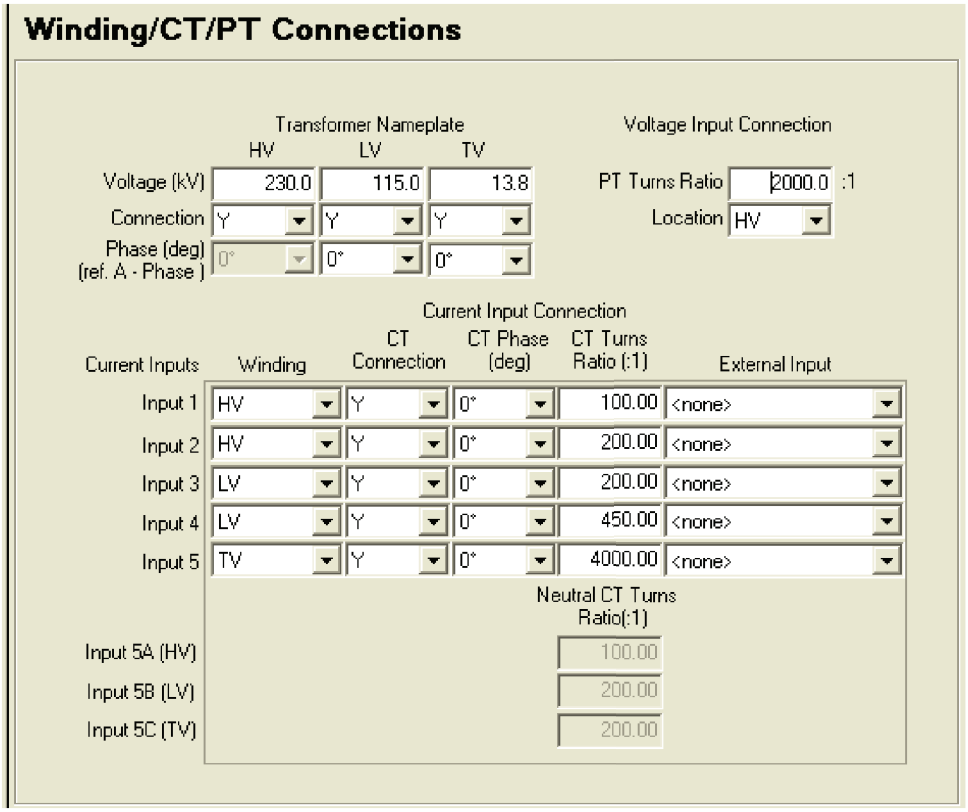


Figure 6.11: Windings /CT

These settings provide the T-PRO with the information related to CT ratios, winding connections (wye or delta), main winding nominal voltage and main winding connection. The relay allows any combination of wye and delta connections.

The field location associated with the PT ratio is user-selectable and you can connect to the HV or the LV side. The field toggles when clicked between HV and LV.

You can assign five sets of AC currents to the HV, LV, TV sides or to NC (not connected). Assigning a current to NC makes it available for recording only.

In our example of Figure 6.11: Windings /CT:

- Inputs 1 & 2 are assigned to the HV (high voltage) side
- Inputs 3 & 4 are assigned to the LV (low voltage) side
- Input 5 is assigned to the TV (tertiary voltage) side

The current inputs must have at least one input on each of the HV, LV and TV side. An error message appears if this is violated. If the 51N or 87N functions are used, they shall use analog input # 5.

You can use the 87N in T-PRO for autotransformers provided there is a neutral CT and the HV and LV CTs are wye connected. If that is the case, analog input IA5 (normally associated with HV) becomes the input for this current. IB5 and IC5 are then not used for protection. However, they could be used to record currents from other CT sources.

T-PRO allows assignment of external control of each ac input as indicated in Figure 6.11: Windings /CT. In this example the ac current inputs 1, 2, 3 are controlled by external inputs 1, 2, 3 respectively. The ac current input will be internally turned off when the corresponding external input is high. In general, each of 5 ac current inputs can be controlled by any of the relay's external inputs and the differential and overcurrent protections will automatically adapt to the configuration change in real time.

Table 6.10: Winding CT Connection

Transformer Nameplate			
Winding	HV	LV	TV
Voltage (kV)	LV to 1000.0	TV to HV	1.0 to LV
Connection	Choose delta or wye	Choose delta or wye	Choose delta or wye
Phase (degree)	0, 30, 60, 90, 120, 150, 180, -150, -120, -90, -60, -30 (Options depend on wye or delta connection)		
Voltage Input Connection			
PT Turns Ratio (:1)	1.0 to 10000.0		
Location	HV or LV		
Current Input Connection			
Current Input	1 to 5		
Winding	HV, LV, TV, NC, 51N/87N (for Input 5), 87N auto (for Input 5)		
CT Connection	Choose delta or wye		
CT Phase (degree)	0, 30, 60, 90, 120, 150, 180, -150, -120, -90, -60, -30 (Options depend on wye or delta connection)		
CT Turns Ratio (:1)	1.00 to 50000.0		
External Control	None, EI 1 to EI 20		
Neutral CT Turns Ratio (:1)	1.00 to 50000.0		

Zig-Zag Transfomer Support

When creating a setting file for a zig-zag transformer, user shall configure the zig-zag side of the winding as a Y connection. Winding connections and phase angle options corresponding to commonly used zig-zag transformer types are summarized in Table 6.11: on page 6-20. In these settings, High voltage (HV) side of the windings are used as the reference.

Table 6.11: Zig Zag Transformer Support

Zig Zag Transformer Type	Connection		LV Phase (Degree)
	HV (Ref)	LV	
DZ0	delta	wye	0
YZ1	wye	wye	-30
YZ5	wye	wye	-150
DZ6	delta	wye	180
YZ11	wye	wye	30
DZ2	delta	wye	-60
DZ4	delta	wye	-120
YZ7	wye	wye	150
DZ8	delta	wye	120
DZ10	delta	wye	60

Temperature Scaling

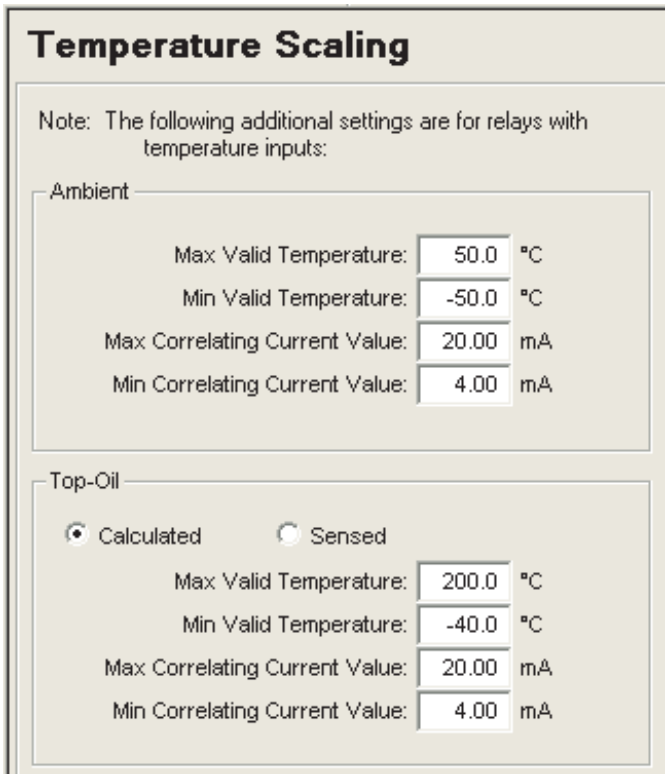

Temperature Scaling
Note: The following additional settings are for relays with temperature inputs:
Ambient
Max Valid Temperature: 50.0 °C
Min Valid Temperature: -50.0 °C
Max Correlating Current Value: 20.00 mA
Min Correlating Current Value: 4.00 mA
Top-Oil
Calculated
Sensed
Max Valid Temperature: 200.0 °C
Min Valid Temperature: -40.0 °C
Max Correlating Current Value: 20.00 mA
Min Correlating Current Value: 4.00 mA

Figure 6.12: Temperature Scaling

Ambient and Top Oil Temperature

The Ambient and Top Oil temperatures are related to a corresponding milliamp (mA) input current quantity. The upper and lower temperature levels correspond to upper and lower mA levels. If the mA input received is outside of this range, an alarm will be initiated to indicate the over or under condition. You can also set whether the top oil is sensed or calculated.

Table 6.12: Temperature Scaling

Ambient	
Maximum Valid Temperature (degrees)	x to 50.0, x = Minimum Valid Temperature +10°
Minimum Valid Temperature (degrees)	-50.0 to x, x = Maximum Valid Temperature -10°
Maximum Current Value (mA)	x to 20.00, x = Minimum Current Value +1 mA
Minimum Current Value (mA)	4.00 to x, x = Maximum Current Value -1 mA
Top Oil	

Table 6.12: Temperature Scaling	
Calculated	Enable/disable
Sensed	Enable/disable
Maximum Valid Temperature (degrees)	x to 200.0, x = Minimum Valid Temperature +10°
Minimum Valid Temperature (degrees)	-50.0 to x, x = Maximum Valid Temperature -10°
Maximum Current Value (mA)	x to 20.00, x = Minimum Current Value +1 mA
Minimum Current Value (mA)	4.00 to x, x = Maximum Current Value -1 mA

SCADA Communication

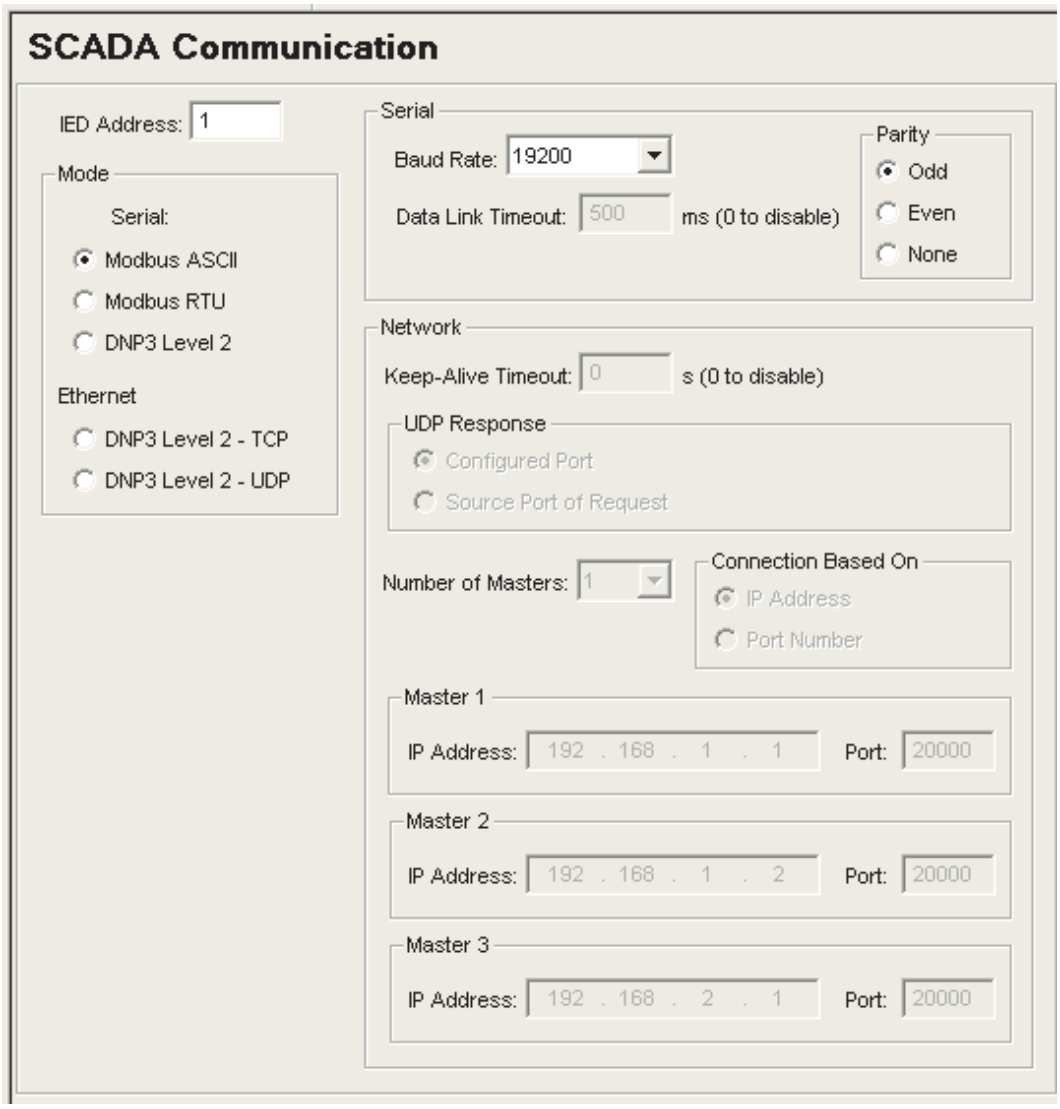


Figure 6.13: SCADA Communication

The relay has configurable SCADA communication parameters for both Serial and Ethernet (TCP and UDP). For DNP3 Level 2 (TCP) up to 3 independent Masters are supported.

DNP Configuration

DNP Configuration - Class Data

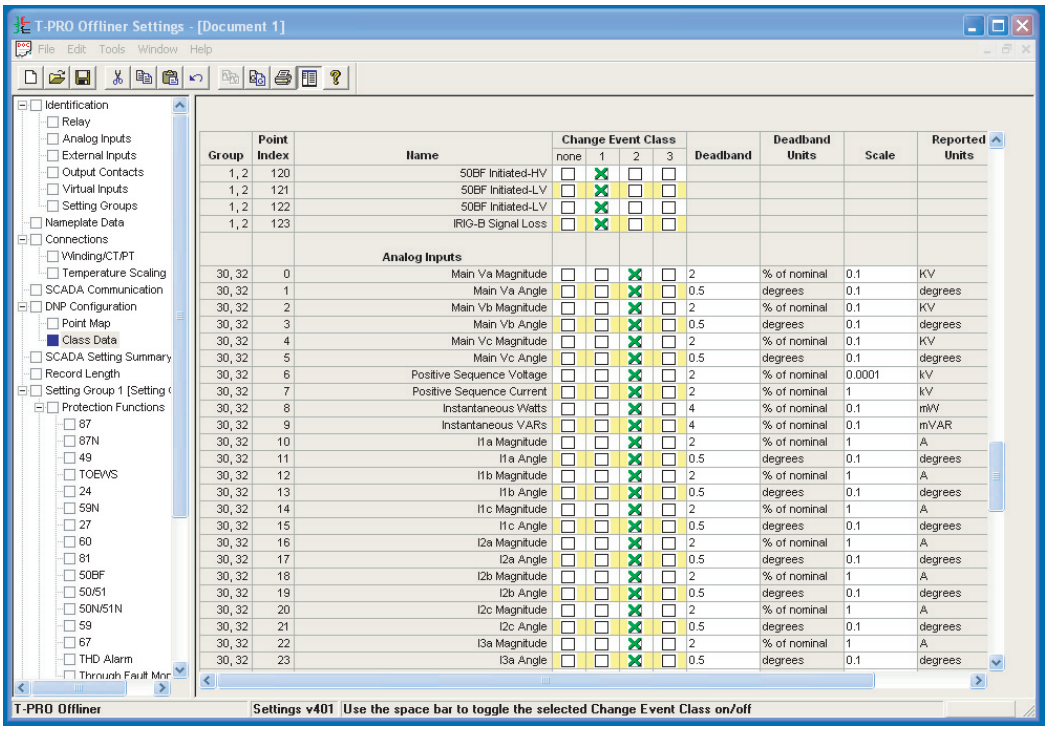

T-PRO Offliner Settings - [Document 1]
File Edit Tools Window Help
Identification
Relay
Analog Inputs
External Inputs
Output Contacts
Virtual Inputs
Setting Groups
Nameplate Data
Connections
Winding/CT/PT
Temperature Scaling
SCADA Communication
DNP Configuration
Point Map
Class Data
SCADA Setting Summary
Record Length
Setting Group 1 [Setting
Protection Functions
87
87N
49
TOEWS
24
59N
27
60
81
50BF
50/51
50N/51N
59
67
THD Alarm
Through Fault Mon
Group
Point Index
Name
Change Event Class
none
1
2
3
Deadband
Deadband Units
Scale
Reported Units
1, 2 120 50BF Initiated-HV
1, 2 121 50BF Initiated-LV
1, 2 122 50BF Initiated-LV
1, 2 123 IRIG-B Signal Loss
Analog Inputs
30, 32 0 Main Va Magnitude 2 % of nominal 0.1 KV
30, 32 1 Main Va Angle 0.5 degrees 0.1 degrees
30, 32 2 Main Vb Magnitude 2 % of nominal 0.1 KV
30, 32 3 Main Vb Angle 0.5 degrees 0.1 degrees
30, 32 4 Main Vc Magnitude 2 % of nominal 0.1 KV
30, 32 5 Main Vc Angle 0.5 degrees 0.1 degrees
30, 32 6 Positive Sequence Voltage 2 % of nominal 0.0001 kV
30, 32 7 Positive Sequence Current 2 % of nominal 1 kV
30, 32 8 Instantaneous Watts 4 % of nominal 0.1 mW
30, 32 9 Instantaneous VARs 4 % of nominal 0.1 mVAR
30, 32 10 I1a Magnitude 2 % of nominal 1 A
30, 32 11 I1a Angle 0.5 degrees 0.1 degrees
30, 32 12 I1b Magnitude 2 % of nominal 1 A
30, 32 13 I1b Angle 0.5 degrees 0.1 degrees
30, 32 14 I1c Magnitude 2 % of nominal 1 A
30, 32 15 I1c Angle 0.5 degrees 0.1 degrees
30, 32 16 I2a Magnitude 2 % of nominal 1 A
30, 32 17 I2a Angle 0.5 degrees 0.1 degrees
30, 32 18 I2b Magnitude 2 % of nominal 1 A
30, 32 19 I2b Angle 0.5 degrees 0.1 degrees
30, 32 20 I2c Magnitude 2 % of nominal 1 A
30, 32 21 I2c Angle 0.5 degrees 0.1 degrees
30, 32 22 I3a Magnitude 2 % of nominal 1 A
30, 32 23 I3a Angle 0.5 degrees 0.1 degrees
T-PRO Offliner
Settings v401
Use the space bar to toggle the selected Change Event Class on/off

Figure 6.14: DNP Configuration - Class Data

Class data for each DNP point can be assigned on the Class Data screen. Only Points which were mapped in the Point Map screen will appear here. Sections for Binary Inputs and Analog Inputs appear here; Binary Outputs cannot be assigned a Class. The list is scrollable by using the scroll control on the right hand side.

In addition to assigning a Change Event Class to each mapped point, most Analog Inputs can also be assigned a Deadband and Scaling factor.

DNP Configuration - Point Map

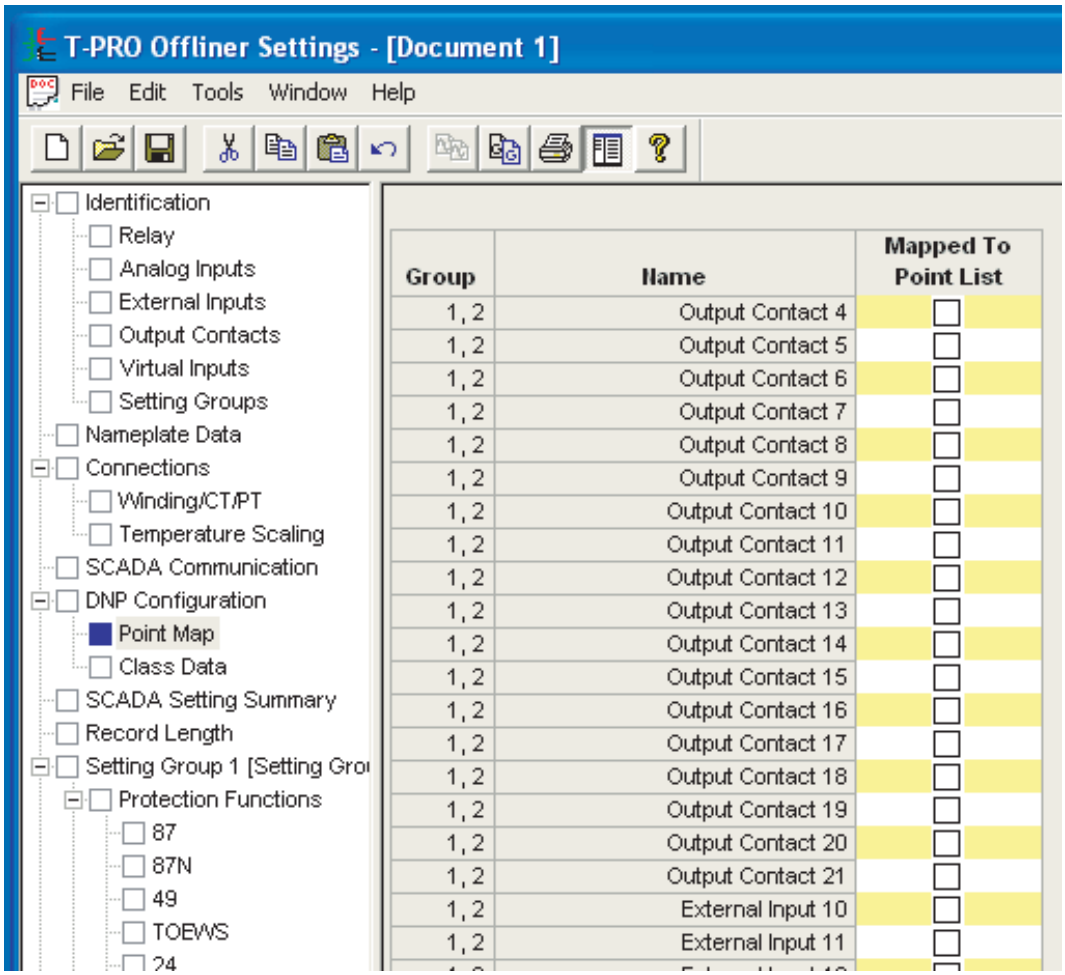


Figure 6.15: DNP Configuration - Point Map

The relay has configurable DNP point mapping. On the Point Map screen, any of the configurable points may be added or removed from the Point List by clicking (or using the cursor keys and space bar on the keyboard) on the associated check box. A green 'X' denotes that the item will be mapped to the Point List.

The list contains separate sections for Binary Inputs, Binary Outputs, and Analog Inputs. The list is scrollable by using the scroll control on the right hand side.

SCADA Settings Summary

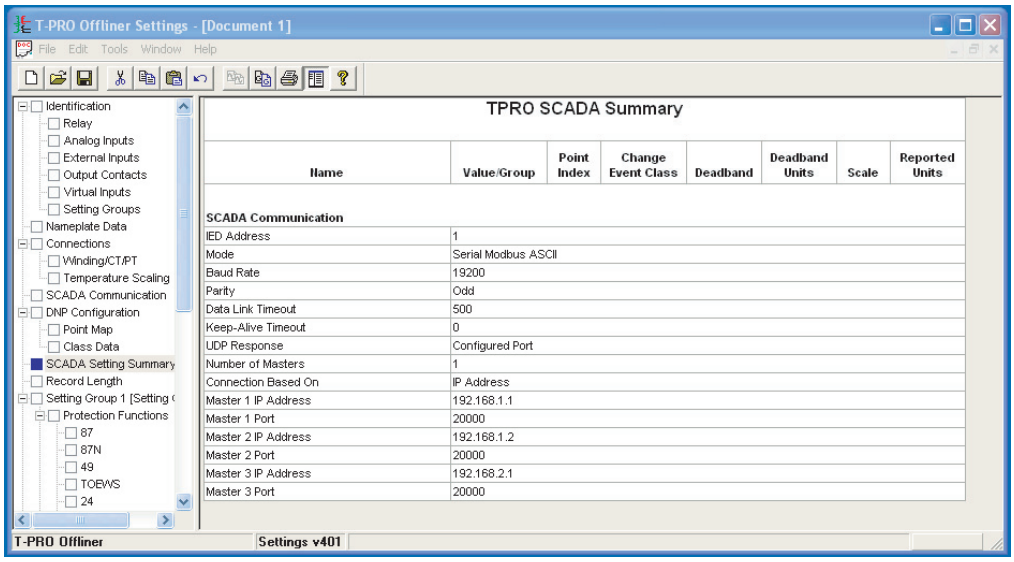


Figure 6.16: SCADA Settings Summary

This screen provides a summary of the current SCADA settings as set in the working setting file. This includes SCADA Communication parameters and (if the SCADA mode is set to DNP) Binary Input, Binary Output, and Analog Input information including Deadband and Scaling factors.

This SCADA Summary screen is scrollable and can be printed.

Record Length

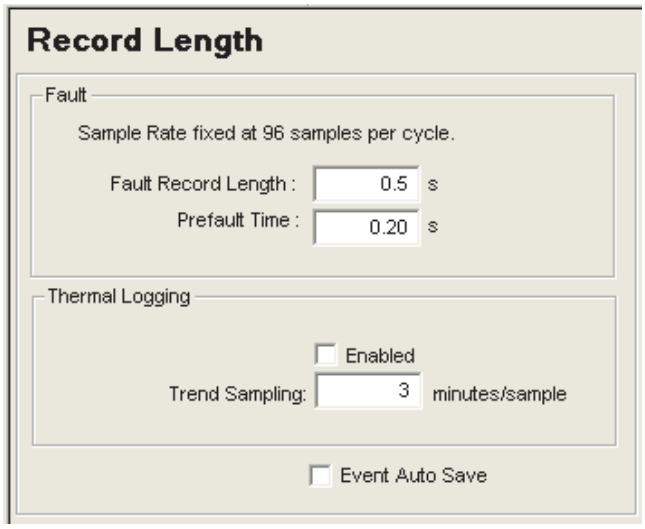


Figure 6.17: Record Length

Define the fault recording record length and the Output Matrix characteristics.

- Fault record sampling rate fixed at 96 samples per cycle
- Record length is settable between 0.2 and 10 seconds
- Prefault time is settable from 0.10 to 2.00 seconds.
- Thermal logging rate is settable between 3 and 60 minutes per sample.

Table 6.13: Record Length	
Fault	
Prefault time is configurable between 0.10 to 2.00 seconds.	
Sample Rate fixed at 96 samples per cycle.	
Fault Record Length (seconds)	0.2 to 10.0
Thermal Logging	Settable between 3 and 60 minutes
Trend Sampling (minutes/sample)	3 to 60
Event Auto Save	Enable/Disable

Setting Groups

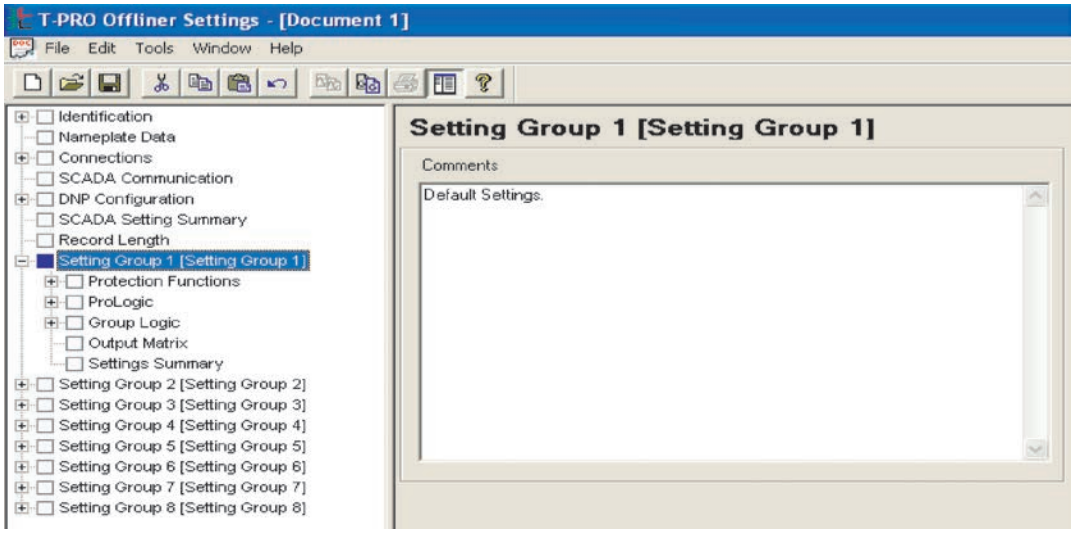


Figure 6.18: Setting Groups Comments

The relay has 8 setting groups (SG). The user can change all relay setting parameters except the physical connections such as input or output parameters in each setting group. Use any one of the 16 available Group Logic Statements per setting group to perform Setting Group changes. The Group Logic statements are similar to the ProLogic statements with the following exceptions, the sole function is to activate one of the 8 setting groups and the processing is in a slower half second cycle. Group Logic inputs statements can be driven from ProLogic or any external input or virtual input or from previous Group Logic

statements. Each Group Logic statement includes 5 inputs (with Boolean statements), one latch state and one pickup delay timer. View the active setting group (ASG) from the Terminal Mode, from the front panel or from a record stored by the relay (the active setting group is stored with the record).

Protection Functions

The protection function features are described in detail, “Protection Functions and Specifications” on page 4-1.

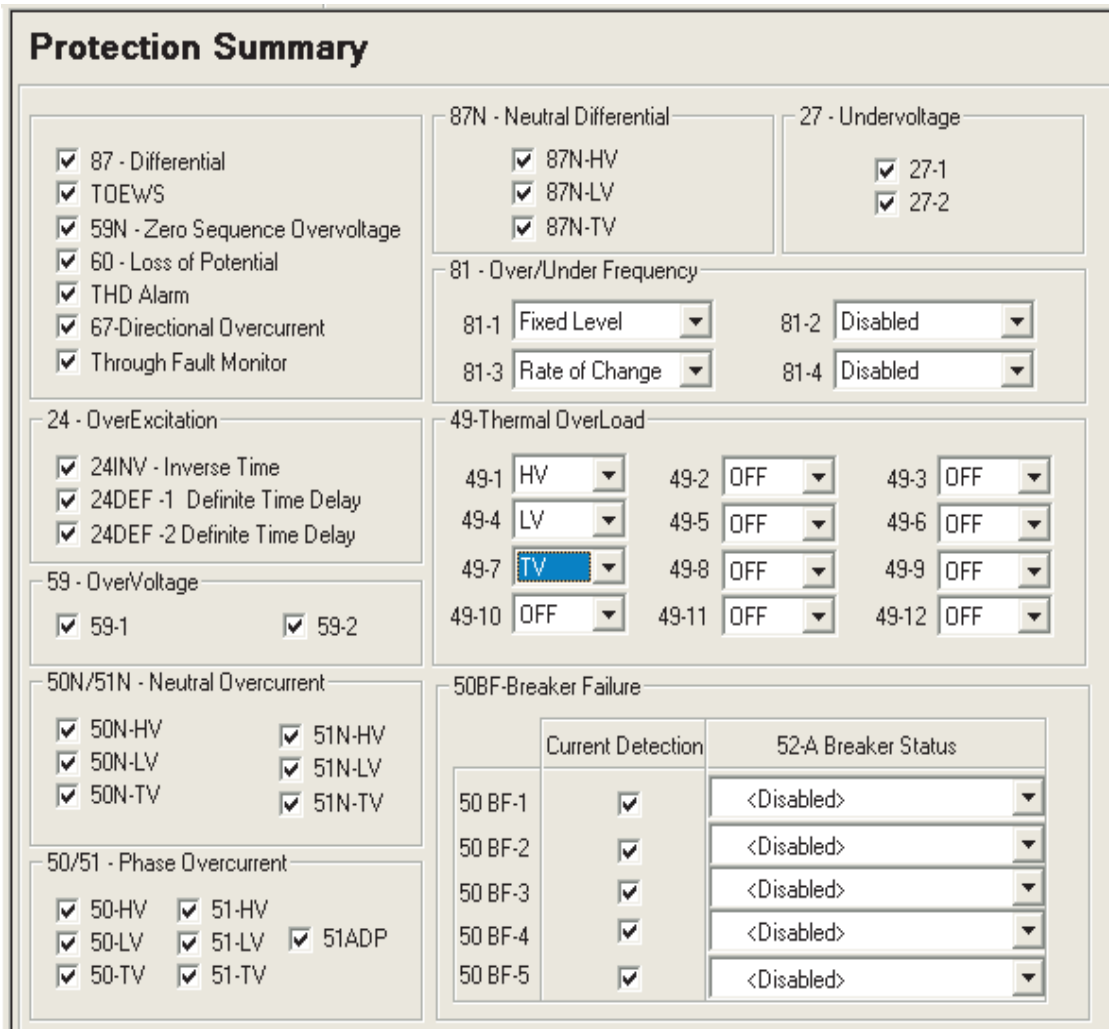


Figure 6.19: Protection Functions

ProLogic

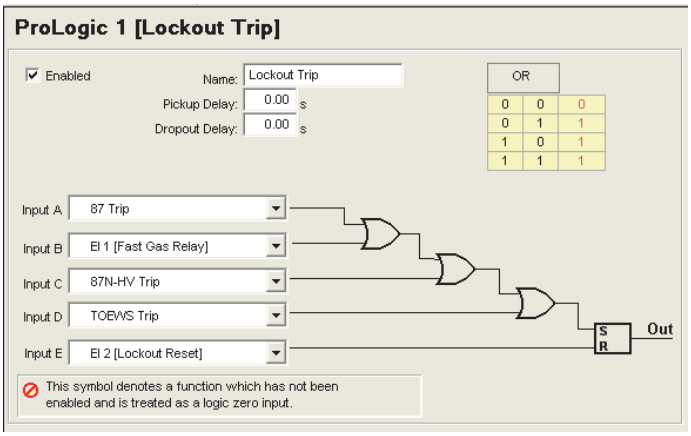


Figure 6.20: ProLogic Example - Lockout Trip

The T-PRO's ProLogic feature provides Boolean control logic (graphically-driven) with multiple inputs combined through logic gates and a timer to create a custom element or function. Up to 24 ProLogic control statements can be created and the logic outputs can be used to provide a variety of functions, such as: provide a breaker status, switch setting group, initiate a recording, provide an output.

You can provide a meaningful name for the function you are creating and apply a pickup and dropout delay. Start with Input A by selecting any of the relay functions or digital inputs from the pulldown list. Repeat for up to 5 possible inputs. Combine these inputs with INVERT, AND, OR, NAND, NOR, XOR, XNOR, LATCH gates by clicking on the gate. Invert the input by clicking on the input line.

The output of ProLogic 1 can be nested into ProLogic 2, ProLogic 1 and ProLogic 2 can be nested into to ProLogic 3 and so forth. The ProLogic may be mapped to one of the user configurable LED's in the Output Matrix screen. The operations of the ProLogic statements are logged in the events listing. ProLogic high and low states are also shown in the fault recordings.

The Figure 6.20: on page 6-29 shows possible ProLogic settings to produce a lockout output. In the example, operation of device 87, receipt of Fast Gas Trip, operation of device 87N or TOEWS trip results in a lockout trip where an output contact is held closed until a lockout reset input is received. This lockout reset quantity could be an external input, virtual input or another function within the relay.

Output Matrix

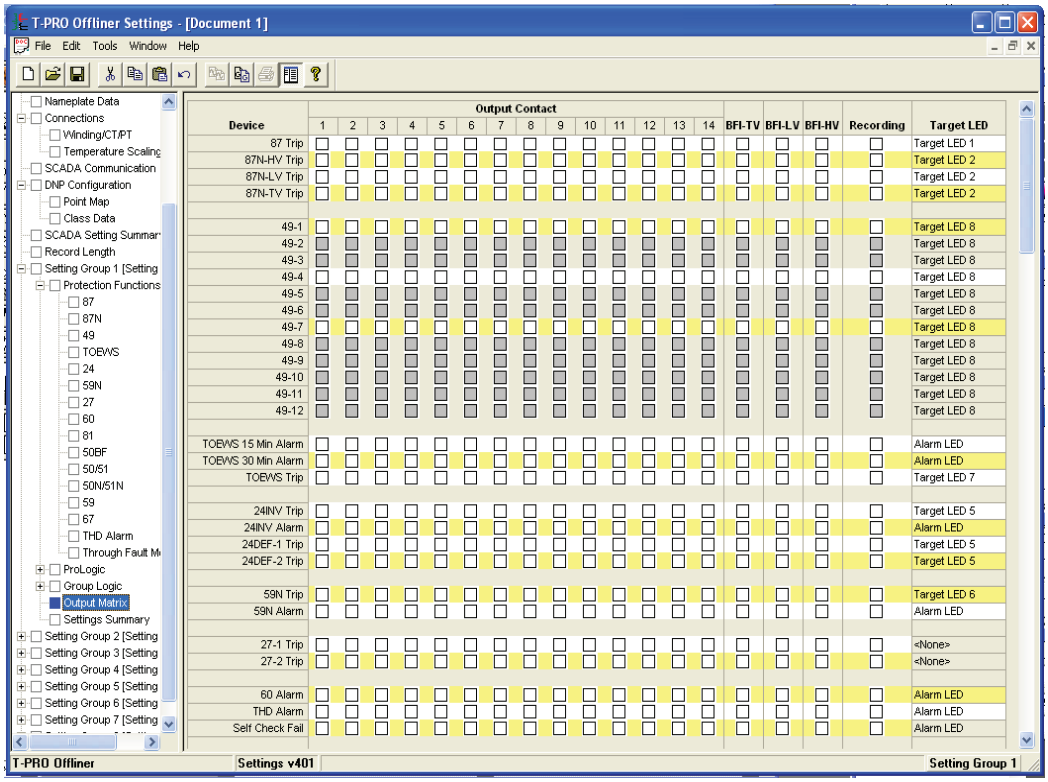


Figure 6.21: Output Matrix

The Output Matrix is where the user shall assign Protection Functions to Outputs contacts, initiate breaker fail, trigger Fault Recordings and to illuminate Target LEDs.

All of the Protection Functions, ProLogics, External Inputs and Virtual Inputs are organized into horizontal rows with all of the names listed in the left-most column. Disabled elements have their rows greyed-out, will be ignored by the relay and cannot be selected in the Output Matrix as long as the element remains disabled. A scroll bar at the right of the Output Matrix allows you to scroll up and down to reveal all of the rows. The top row defines the purpose of each column, including, output contact numbers, breaker fail initiates for the HV, LV and TV breakers, transient fault recording and Target LED.

Each coordinate, where the row (input element) meets a column (output element), is defined by a check box. Each column of check boxes can be thought of a one large OR gate. Place the mouse cursor over the check box at the desired coordinate and click to toggle the status between mapped and unmapped. A mapped check box will be marked with a green “X”.

The extreme right column has a drop-down pick list in each cell, where the user selects the LED (or none) that should be illuminated by the protection function of same row.

Protection Elements labeled as Alarm (e.g., “24INV Alarm”) are activated by the pickup of the element when the element’s threshold has been exceeded

(i.e., when the element's timer is initiated). These elements are typically used for testing purposes.

All output relays have a fixed 0.1 second stretch time after the dropout of the initiating element.

For a particular function to operate correctly, it must be enabled and must also have its logic output assigned to at least one output contact if it is involved in a tripping function.

Print the entire output matrix by selecting the printer icon. This printout is produced on multiple pages determined by the your "Print Setup" settings. Typical print setup to not split the columns on letter size paper could be: Landscape, Scaling approximately 80%. It's recommended to preview the print job for your printer settings and making any require scaling adjustments prior to executing the final print command.

Setting Summary

You may print the settings for all elements, or you may choose to print the Enabled element settings only. To print the Enabled protection element settings only, select from the Offliner menu bar: Tools/Options and check “Display And Print Only Enabled Protection Elements”.

To initiate the print output, select “Setting Summary” in the element tree, then click anywhere in the T-PRO Setting Summary area. This will activate the Print icon to enable printing.

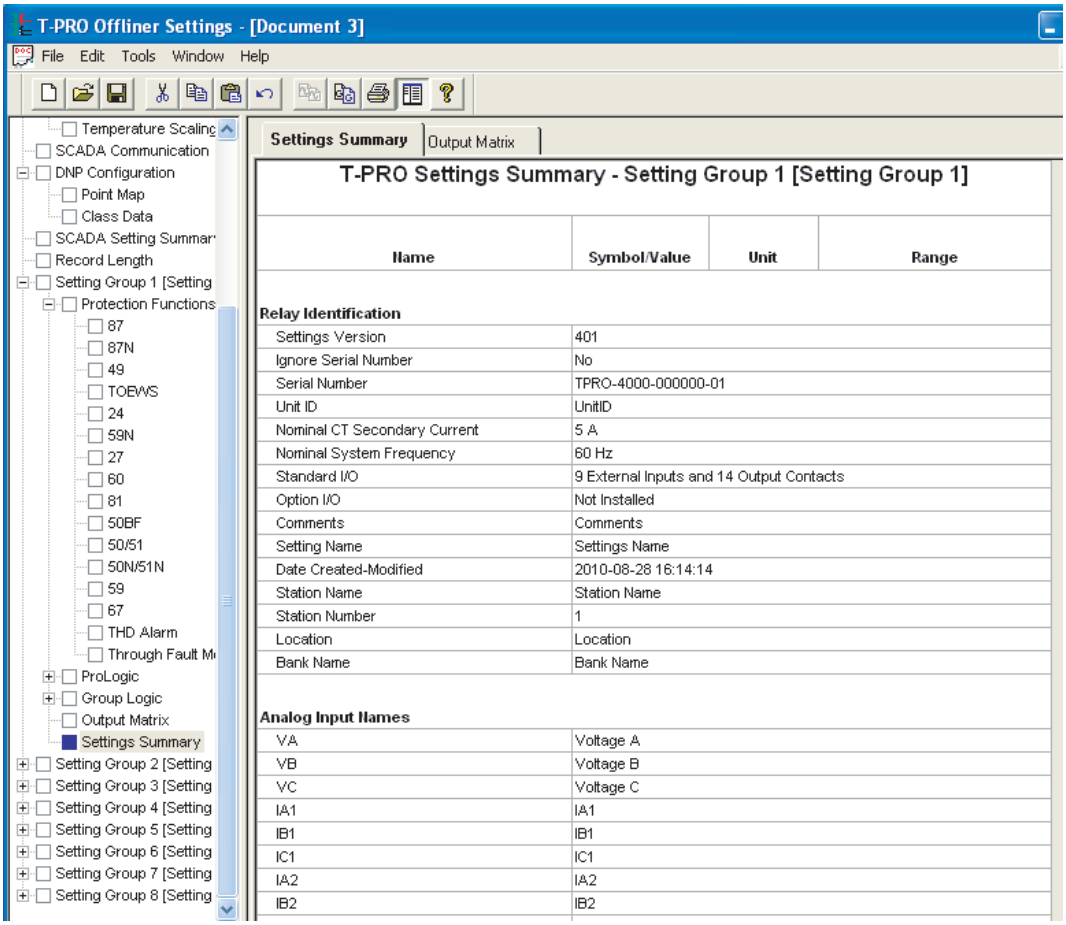


Figure 6.22: Settings Summary

6.6 RecordBase View Software

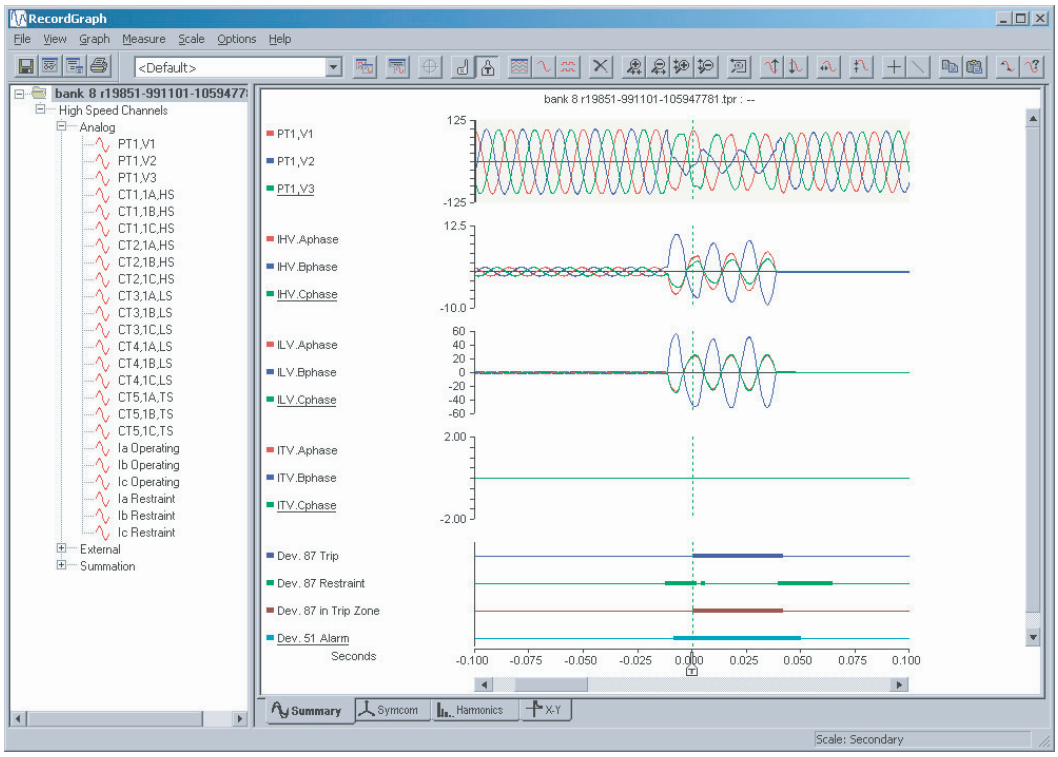


Figure 6.23: RecordBase View

Use RecordBase View to store and analyze the records from a relay.

1. Set the data storage location on your hard drive from within Relay Control Panel. Select *File* and *Set Data Location* dialog box will appear. The relay Records and Setting Files will be saved in your chosen path in your computer.
2. Select one or more records on the relay using the Records function in Relay Control Panel.
3. Initiate transfer of the selected records to your computer.
4. Start the RecordBase View program and use the *File>Open* menu command to open the downloaded record files located in the receive directory specified in step 1.

For further instructions refer to the RecordBase View Manual at the back of the printed version of this manual.

7 Acceptance/Protection Function Test Guide

7.1 Relay Testing

ERLPhase relays are fully tested before leaving the factory. A visual inspection of the relay and its packaging is recommended on receipt to ensure the relay was not damaged during shipping.

> The electronics in the relay contain static sensitive devices and are not user-serviceable. If the relay is opened for any reason exposing the electronics, take extreme care to ensure that you and the relay are solidly grounded.

Generally an analog metering check and a test of the I/O (External Inputs and Output Contacts) upon delivery and acceptance is sufficient to ensure the functionality of the relay. Further tests, according to the published relay specifications in "IED Settings and Ranges" in Appendix B, can be performed at the purchaser's option

The following test section is intended to be a guide for testing the protection elements in the T-PRO relay. The most convenient time to perform these tests is upon receipt and acceptance by the customer, prior to in-service settings being applied. Once the in-service settings are applied, ERLPhase recommends that enabled functions be tested during commissioning to ensure that the intended application is fulfilled.

Test Equipment Requirements

- 3 voltage sources
- 2 sets of 3-phase currents recommended (to test differential element), but can be completed single-phase by using 1 set of 3-phase currents with variable frequency capability.
- 1 ohmmeter
- 1 dc mA calibrating source

or

- a 1 kΩ to 10 kΩ 1.0 Watt variable resistor and a milliammeter up to 25 mA

> Set nominal CT secondary current to either 5 A or 1 A, and nominal system frequency to either 60 Hz or 50 Hz. This example uses 5 A/ 60 Hz.

Calibration

The T-PRO is calibrated before it leaves the factory and should not require recalibration unless component changes are made within the relay.

Before you begin a new calibration establish the accuracy of the equipment being used.

To perform a calibration, you must be logged into the relay in Relay Control Panel at the Service access level:

1. Proceed to the *Utilities>Analog Input Calibration* tab. The Analog Input Calibration screen lists all of the T-PRO analog input channels.
2. Select the channel to calibrate with your mouse (you may select and calibrate multiple channels at once as long as they are the same qualities).
3. Enter the exact Magnitude of the *Applied Signal* you are applying your test source.
4. Execute the *Calibrate Offset and Gain* button.

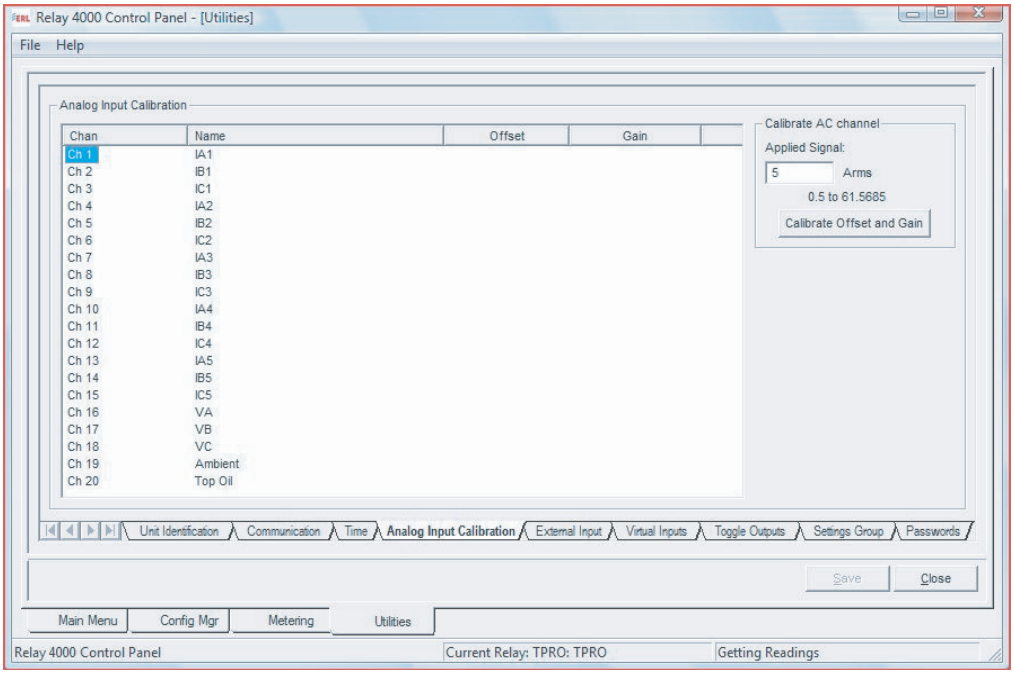


Figure 7.1: Enter the actual applied signal level

If the applied test signal is not reasonable, an error will be displayed and the calibration will not be applied. For example, in Figure 7.2: on page 7-3, the dis-

played calibration error message indicates that we tried to calibrate a 5 amp level with no current applied, which is not reasonable.

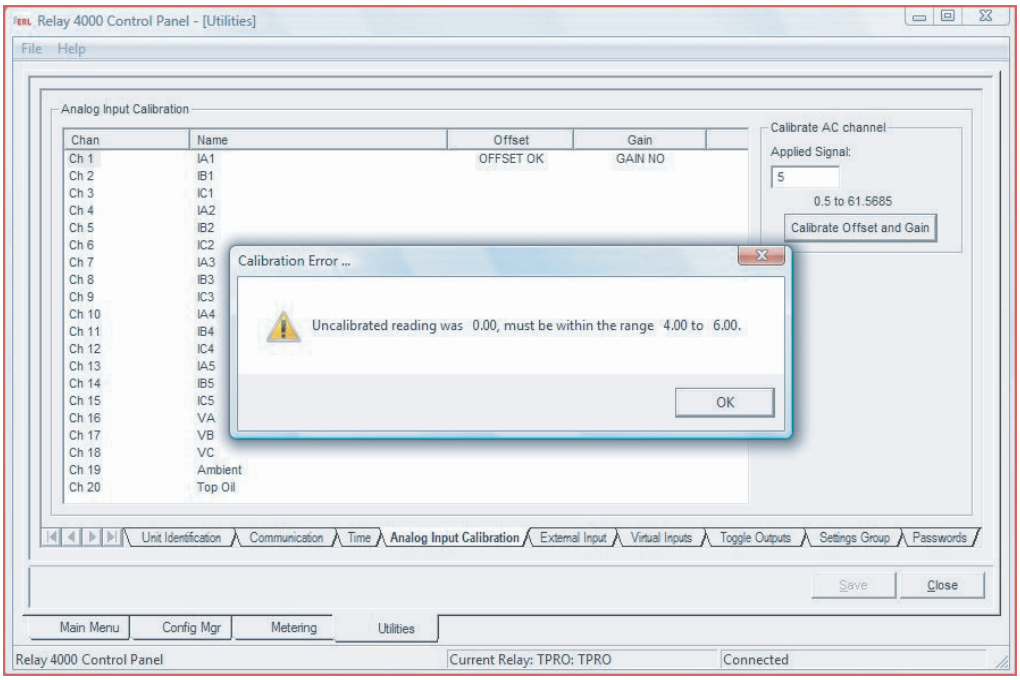


Figure 7.2: Calibration error - out of range

Only the magnitude (gain) and offset are calibrated, not the angle.

When an analog input channel is calibrated, you can verify the quantity measured by selecting the Metering menu and the Analog Quantity submenu.

7.2 Testing the External Inputs

External Inputs are Polarity Sensitive!

To test the external inputs, login to the T-PRO using Relay Control Panel at any access level and select the *Metering>External Inputs* tab which displays the status of all External Inputs (either High or Low). Placing 125 Vdc across each external input in turn will cause the input to change status from Low to High. The external inputs metering screen in Relay Control Panel has approximately 0.5 second update rate.

7.3 Testing the Output Relay Contacts

Access the T-PRO service level in Relay Control Panel. Open the *Utilities>Toggle Outputs* tab screen. To toggle outputs you first need to enter *Test Mode* by selecting the *Relay in Test Mode* check box. When you check the box, a message will appear prompting you to confirm that you really want to enter this mode.

Once you enter Test Mode, the red *Test Mode* LED on the front of the T-PRO will illuminate and it will remain illuminated until you exit Test Mode. The protection functions cannot access the output contacts in Test Mode; they are controllable only by the user via Relay Control Panel.

To toggle a particular output, select it from the drop down list and then click on the *Closed* button. You can verify the contact is closed with an ohmmeter. The contact will remain closed until you either click the *Open* button or exit Test Mode.

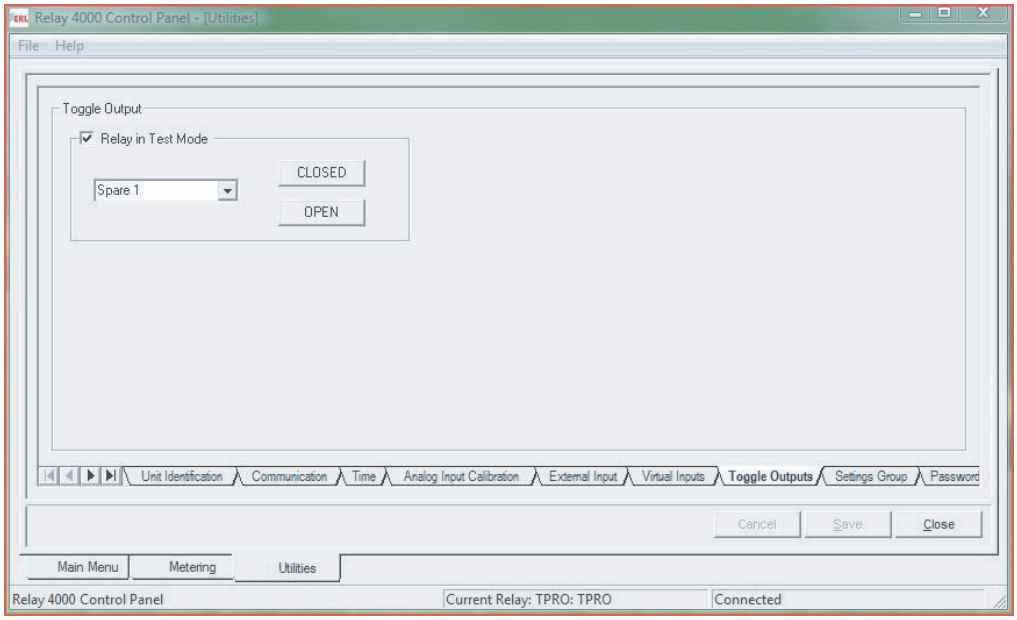


Figure 7.3: Test Output Contacts

7.4 T-PRO Test Procedure Outline

Devices to Test

- 60 - AC Loss of Potential
- 24INV - Time Inverse Overexcitation (v/f)
- 24DEF - Definite Time Overexcitation
- 59N - Zero Sequence Overvoltage
- 27 - Undervoltage
- 81-1 - Set to fixed Over Frequency
- 81-3 - Set to fixed Under Frequency
- 50N/51N - Neutral Overcurrent
- 67 - Directional Overcurrent
- 67N - Directional Earth Fault
- 50/51 - Phase Overcurrent
- 51 ADP - Adaptive Overcurrent
- Top Oil Temperature Alarm
- Ambient Temperature Alarm
- 49 - Thermal Overload
- 49 - TOEWS
- 59 - Overvoltage
- 50BF - Breaker Fail
- 87 - Differential (Single- and Three-Phase)
- THD Alarm
- 87N - Neutral Differential

Settings and Transformer Connections

In order to clarify the expected relay action for each test, the settings are provided in the test examples. Alternately, you could substitute the settings in this procedure with your own settings and modify the test accordingly using the described calculation processes.

The Nameplate and Connection settings for tests that follow are:

- MVA: 100
- Windings: 2
- HV kV: 230 Y (0°)
- LV kV: 115 Delta (-30°)
- HV CT: 250:1 Y (0°)
- LV CT: 500:1 Y (0°)
- PT Location: HV Side
- Base Frequency: 60 Hz (1.0 per unit frequency)

Calculated Values

The PT location is on the HV side, therefore the reference side is HV.

Nominal secondary phase to phase voltage = $\frac{HVkV}{PTratio} = \frac{230kV}{2000} = 115.0V$ (1)

Nominal secondary phase to neutral voltage = $\frac{115}{\sqrt{3}} = 66.4V$ (2)

Primary Ibase = $\frac{kVA}{\sqrt{3} \cdot kV} = \frac{100e3}{\sqrt{3} \cdot 230} = 251A$ (3)

Secondary Ibase = $\frac{PrimaryIbase}{CTratio} = \frac{251A}{250} = 1.004A$ (4)

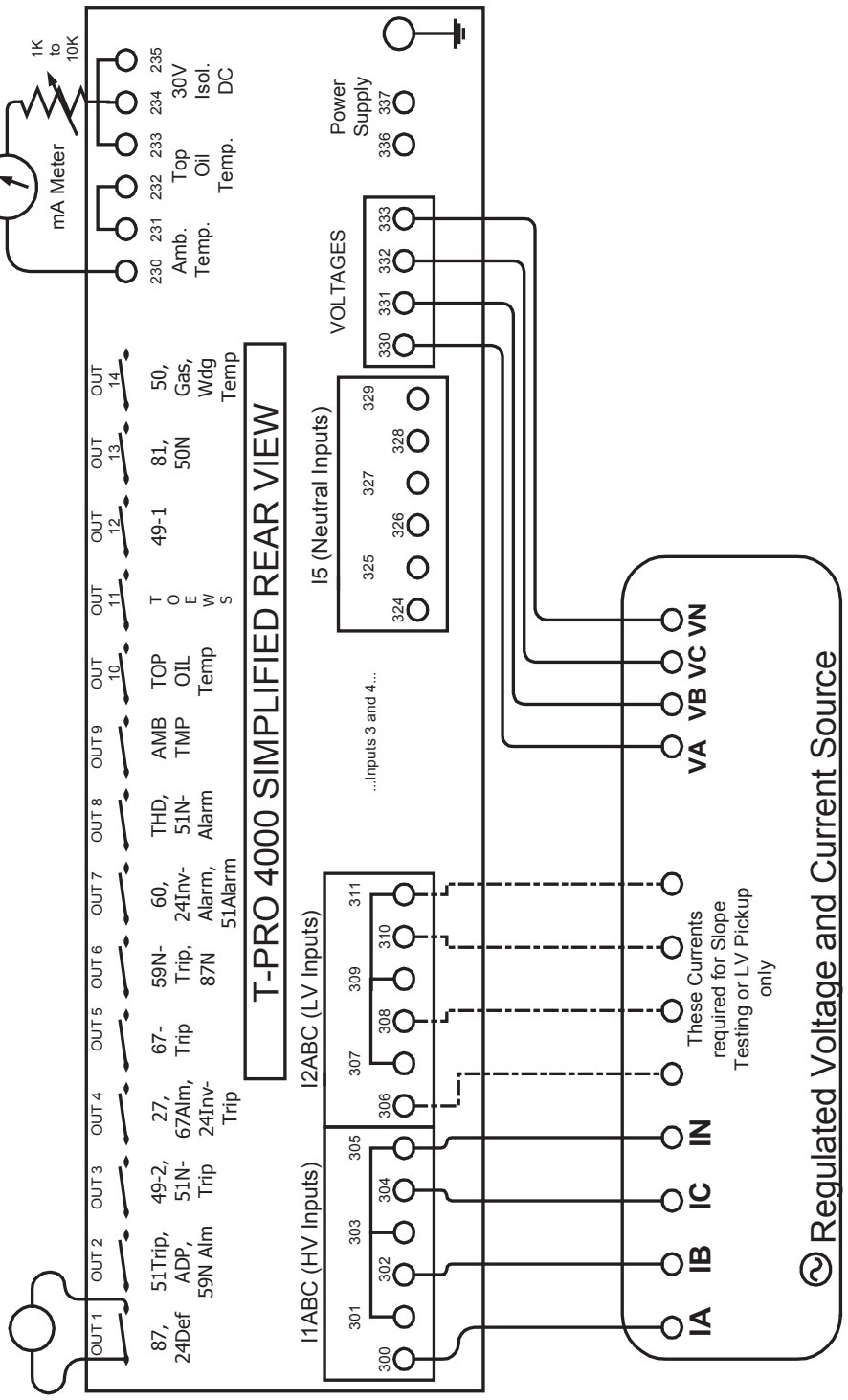


Figure 7.4: Suggested Test Connections for Acceptance Tests

Note 1

Where each test specifies "*Metering>Logic* tab", you view the following Relay Control Panel metering screens:

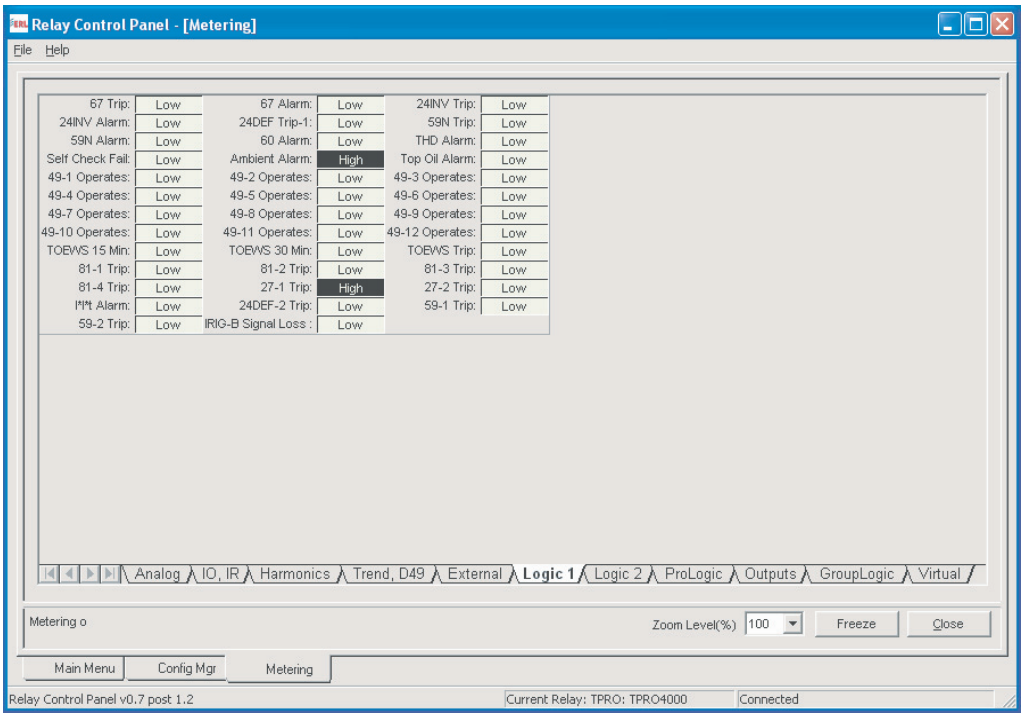


Figure 7.5: Metering Logic 1

60 Loss of Potential Test

Settings (only Enable Setting can be modified)

- Voltage = 0.5 per unit on 1 or 2 phases (does not operate on loss of 3 phases).
- As shown in Figure 7.6: on page 7-9 map the 60 element mapped to Out 7 in the Output Matrix.

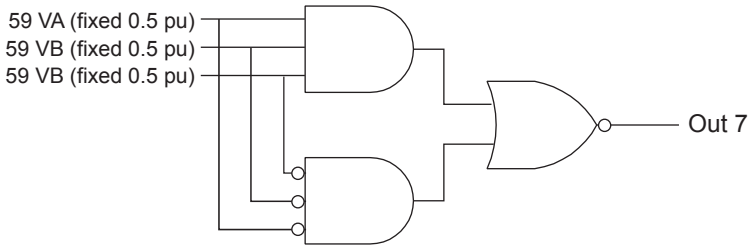


Figure 7.6: Logic, Loss of Potential (60)

60 Test Procedure

1. Access Relay Control Panel *Metering>Logic 1* or Front HMI, *Metering>Logic>Logic Protections 1*.
2. Monitor the following element for pickup: “60 Alarm”.
3. Apply balanced 3-phase nominal voltage (66.4 V) to the T-PRO terminals:

   Ph A: 330, 66.4 V ∠0 °

   Ph B: 331, 66.4 V ∠-120 °

   Ph C: 332, 66.4 V ∠+120 °

   Ph N: 333
4. Observe: 60 Alarm = Low.
5. Remove the voltage from any single phase:

   60 Alarm = High
6. Turn all voltage off.

   60 Alarm = Low

Timing Test

1. Monitor timer stop on 60 Alarm Contact *(Output Contact 7in our settings)*.
2. Apply 3 phase voltages as in Step 3 above.
3. Set timer to start from single-phase 66.4 V to 0 V transition (i.e. V On to V Off).
4. Time from V Off to Out 7 Closed (expect 10 seconds).
5. End of 60 test.

24 Overexcitation Test

Settings

- 24INV Pickup = 1.2 per unit = 1.2 * 66.4 V @ 60 Hz = 79.7 V @ 60 Hz
- K = 0.1
- 24DEF Pickup = 1.25 per unit = 1.25 * 66.4 V @ 60 Hz = 83 V @ 60 Hz
- As shown in Figure 7.7: on page 7-10, map the elements to outputs in the Output Matrix:

  Map 24INV Alarm to Out7

  Map 24INV Trip to Out4

  Map 24DEF to Out1

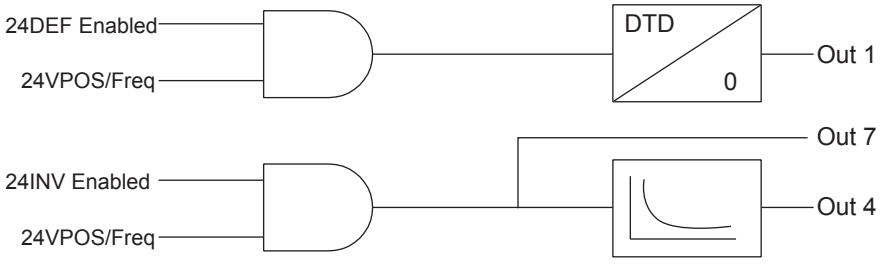


Figure 7.7: Logic, Overexcitation (24)

24INVerse and 24DEFinite Test Procedure

1. Access Relay Control Panel *Metering>Logic 1* or Front HMI, *Metering>Logic>Logic Protections 1*.
2. Monitor the following elements for pickup: 24INV Alarm, 24DEF Trip.
3. Apply balanced 3-phase nominal voltage at nominal frequency to the T-PRO terminals:

   Ph A: 330, 66.4 V ∠0 °
   Ph B: 331, 66.4 V ∠-120 °
   Ph C: 332, 66.4 V ∠+120 °
   Ph N: 333

4. Slowly ramp the 3-phase voltage up.

   At 79.5 – 80.5 V (expect 79.7 V):

   24INV Alarm = High

   At 82.5 – 83.5 V (expect 83.0 V):

   24DEF Trip = High

5. Turn voltages off.

   24INV Alarm = Low

   24DEF Trip = Low

24INV Timing Test

1. Monitor timer stop on 24INV Trip Contact *(Output Contact* 4 in our settings).
2. Set timer to start from 3-phase 0.0 V to 86.3 V transition (this equates to 1.3 per unit @ 60 Hz)

$$\text{Time Delay} = \frac{K}{\left[\frac{v}{f} - Pickup\right]^2} = \frac{0.1}{\left[\frac{\left(\frac{86.3}{66.4}\right)}{60} - \frac{\left(\frac{79.68}{66.4}\right)}{60}\right]^2} = \frac{0.1}{0.01} = 10s \qquad (5)$$

Where: *v* is the per unit voltage
f is the per unit frequency.
Vary either *v* or *f*.
In this example we're varying v only (with frequency fixed @ 60 Hz = 1.0 per unit).

3. End of 24 test.

59N Zero Sequence Overvoltage ($3V_0$) Test

Settings

- 59N ($3V_0$) Pickup = 75 V
- Time Curve = IEC Standard Inverse

  A = 0.14

  B = 0

  p = 0.02

  TMS = 0.2
- As shown in Figure 7.8: on page 7-12, map elements to outputs in the Output Matrix

  Map 59N Alarm to Out 2

  Map 59N Trip to Out 6

Figure 7.8: Logic, Zero Sequence OverVoltage (59N)

59N (3V0) Test Procedure

1. Access Relay Control Panel *Metering>Logic 1* or Front HMI, *Metering>Logic>Logic Protections 1*.
2. Monitor the following element for pickup: 59N Alarm.
3. Apply 3-phase prefault voltages (all in-phase) to the T-PRO terminals as follows:

   Ph A: 330, 20 V ∠0 °

   Ph B: 331, 20 V ∠0 °

   Ph C: 332, 20 V ∠0 °

   Ph N: 333

Note: The above prefault $3V_0$ = VA + VB + VC = (20V ∠0 ° + 20V ∠0 ° + 20V ∠0 ° = 60V ∠0 °)

4. Slowly ramp the 3-phase voltage up.

   At 24.5 – 25.5 V per phase (expect 25.0 V):

   59N Alarm = High
5. Turn voltage off.

   59N Alarm = Low

Timing Test

1. Monitor timer stop on 59N Trip Contact *(Output Contact 6 in our settings).*
2. Set timer start from 3-phase 0.0 V to 50.0 V transition (all at 0°).

   $3V_0$ = 50∠0 + 50∠0° + 50∠0° = 150 V (This equates to 2x pickup.)

Time Delay = $$TMS \cdot \left[B + \frac{A}{\left(\frac{3VO}{Pickup}\right)^{p} - 1} \right] = 0.2 \cdot \left[0 + \frac{0.14}{\left(\frac{150}{75}\right)^{0.02} - 1} \right] = \left(0.2 \cdot \frac{0.14}{0.014} \right) = 2.0s \quad (6)$$

3. End of 59N test.

27 (27-1 Single-Phase [OR], 27-2 3-Phase [AND] Test)

For this example testing only 27-2 is utilized, configured as a 3 Phase Undervoltage.

Testing 27-1 with the settings specified below is just a matter of enabling 27-1 and reducing only one-phase voltage.

Settings

- 27-1 Gate = OR (single-phase)
- 27-1 Pickup = 50 V secondary
- 27-1 Delay = 0.5 seconds
- 27-2 Gate = AND (3-phase)
- 27-2 Pickup = 50 V secondary
- 27-2 Delay = 0.6 seconds
- As shown in Figure 7.9: on page 7-13, map elements to outputs in the Output Matrix:

  Map 27-2 to Out 4

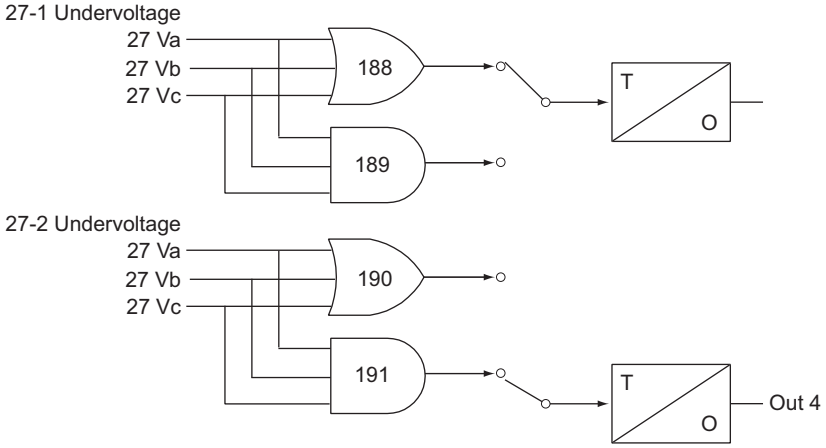


Figure 7.9: Logic, UnderVoltage (27)

27 Three-Phase Undervoltage Test Procedure

1. Access Relay Control Panel *Metering > Logic 1* or Front HMI, *Metering > Logic > Logic Protections 1*.
2. Monitor the following element for pickup: 27-2 Alarm.
3. Apply balanced 3-phase voltage to the T-PRO terminals as follows:

   Ph A: 330, 66.4 V ∠0 °

   Ph B: 331, 66.4 V ∠-120 °

   Ph C: 332, 66.4 V ∠120 °

   Ph N: 333
4. Slowly and simultaneously ramp the 3-phase voltage magnitudes down.

   At 50.5 to 49.5 V per phase (expect 50.0 V):

   27-2 Alarm = High
5. Turn voltages off.
6. End of 27 test.

81 Over/Under Frequency Test

Settings

- 81-1 Over Frequency Pickup = 61 Hz
- 81-2 Over Frequency Rate of Change = 0.1 Hz/second
- 81-3 Under Frequency Pickup = 59 Hz
- 81-4 Under Frequency Rate of Change = -0.1Hz/second
- All Time Delays = 0.2 seconds
- As shown in Figure 7.10: on page 7-15, map elements to outputs in the Output Matrix:

  Map all 81 Trip elements to Out 13

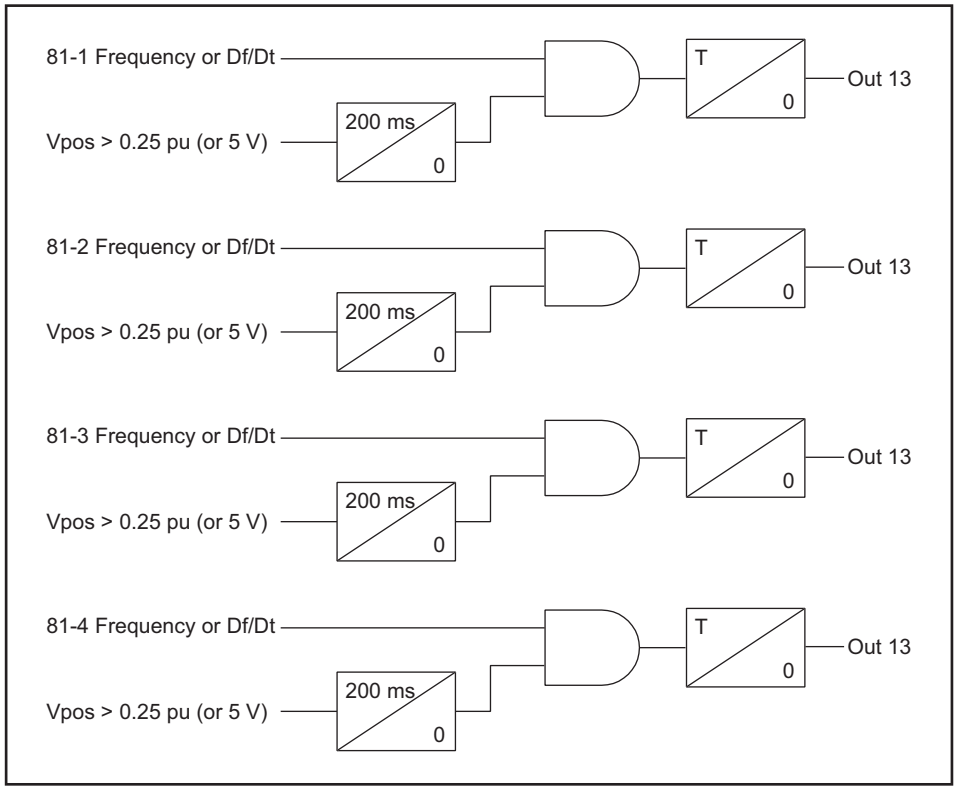


Figure 7.10: Logic, Over/Under/Rate of Change of Frequency (81)

81 Test Procedure

1. Access Relay Control Panel *Metering* > *Logic 1* or Front HMI, *Metering* > *Logic* > *Logic Protections 1*.
2. Monitor the following elements for pickup: 81-1 Trip, 81-3 Trip.
3. Apply balanced 3-phase nominal voltages at nominal frequency to the T-PRO terminals.

   Ph A: 330, 66.4 V ∠0°

   Ph B: 331, 66.4 V ∠-120°

   Ph C: 332, 66.4 V ∠+120°

   Ph N: 333
4. Slowly ramp at < 0.1 Hz/second (e.g. +0.05Hz/second) the 3-phase voltage frequency up towards 61 Hz.

   At 60.99 – 61.01 Hz observe:

   81-1 = High
5. Slowly ramp (> -0.1 Hz/second e.g.: -0.05 Hz/second) the 3-phase voltage frequency down towards 59 Hz.

   At 58.99 – 59.01 Hz observe:

   81-3 = High

6. Turn voltages off.

    81-1 = Low

    81-3 = Low

7. End of 81 test

50N/51N Neutral Instantaneous and Time Overcurrent Test

Settings

- 50N Pickup = 5.0 A
- 51N Pickup = 2.0 A
- Time Curve = IEEE Extremely Inverse

    A = 5.64

    B= 0.0243

    p = 2

    TMS = 5.0

- As shown in Figure 7.11: on page 7-16, map elements to outputs in the Output Matrix:

    50N HV mapped to Out 13

    51N HV Pickup mapped to Out 8

    51N HV Trip mapped to Out 3

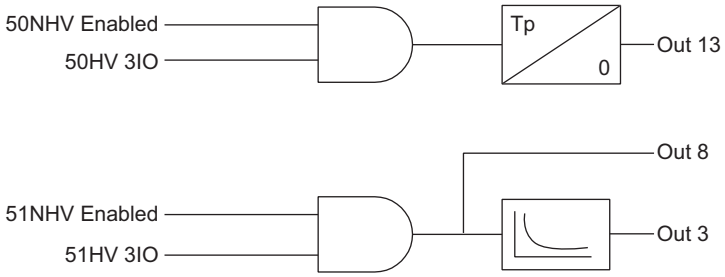


Figure 7.11: Logic, Neutral Instantaneous and Time Overcurrent (50N/51N)

50N and 51N Test Procedure

1. Access Relay Control Panel *Metering* > *Logic 2* or Front HMI, *Metering* > *Logic* > *Logic Protections 2*.
2. Monitor for pickup: 51N Alarm.
3. Apply one-phase current to the T-PRO terminals:

    Ph N: 324 – 325, 1.8 A (note: I5 A is the input for HV neutral)

4. Slowly ramp the current up.

    At 1.95 to 2.05 A (expect 2.00 A):

        51N Alarm = High

5. Continue to raise current.

    At 4.90 to 5.10 A (expect 5.00 A):

        50N Trip = High

6. Turn currents off.

51N Alarm = Low

50N Trip = Low

51N HV Timing Test

1. Monitor timer stop on 51N Trip Contact *(Output Contact 3 in our settings)*
2. Set timer start from one-phase 0.0 amp to 8.00 A transition (This equates to 4x pickup.).

Time Delay =

$$TMS \cdot \left[B + \frac{A}{(I_{multiple})^{p} - 1} \right] = 5 \cdot \left[0.0243 + \frac{5.64}{(4)^{2} - 1} \right] = 5 \cdot \left[0.0243 + \frac{5.64}{15} \right] = 2.00 s \quad (7)$$

3. End of 50N/51N test.

67 Directional Time Overcurrent Test

Settings

- 67 Pickup = 1.2 per unit
- Alpha = 180° (This is the positive sequence current angle start point with respect to positive sequence voltage angle.)
- Beta = 180° (This is the operating "Window". In this case the 67 element should operate between [Alpha to (Alpha + Beta)] = [180° to (180° + 180°)] = 180° to 360°

  Time Curve = IEEE Moderately Inverse

  A = 0.0103

  B = 0.0228

  p = 0.02

  TMS = 8.0

- As shown in Figure 7.12: on page 7-17, map elements to outputs in the Output Matrix:

  67 Pickup mapped to Out 4

  67 Trip mapped to Out 5

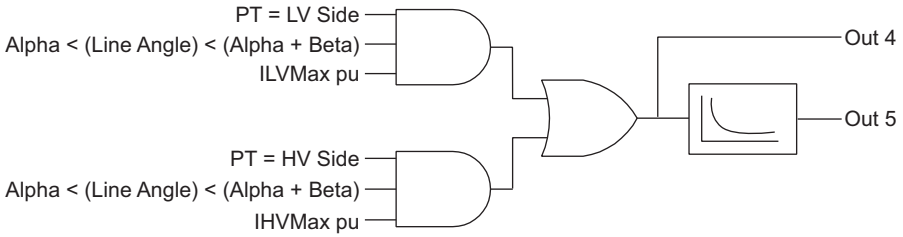


Figure 7.12: Logic, Directional Overcurrent (67)

67 Test Procedure

1. Access Relay Control Panel *Metering>Logic 1* or Front HMI, *Metering>Logic>Logic Protections 1*.
2. Monitor the following element for pickup: 67 Alarm.
3. Following are the default test quantities (future tests will refer to these default test quantities).

   Apply balanced 3-phase currents to the T-PRO terminals as follows:

   Ph A: 300 – 301, 1.0 A ∠-90°

   Ph B: 302 – 303, 1.0 A ∠+150°

   Ph C: 304 – 305, 1.0 A ∠+30°

   (in the test when we refer to ramping Ph A angle, we mean ramp all 3 phase balanced angles simultaneously)
4. Apply single-phase polarizing voltage to:

   Ph A: 330 – 333, 66.4 V ∠0°
5. Slowly ramp the 3-phase currents magnitudes up.

   At 1.15 to 1.25 A (expect 1.20 A):

   67 Alarm = High
6. Increase currents to 2.0 A.

   Observe: 67 Alarm = High
7. Ramp 3 phase current angles in positive direction from -90°.

   At -1.0° to +1.0° (expect 0°):

   67 Alarm = Low
8. Return current angles to -90°, +150, +30.
9. Ramp current angle in negative direction from -90°.

   At -179° to -181° (expect -180°):

   67 Alarm = Low
10. Turn currents OFF (Keep voltage On for the timing test).

    67 Alarm = Low

67 Timing Test

1. Monitor timer stop on 67 Trip Contact *(Output Contact 5 in the settings)*
2. Set timer start from 3-phase currents at default angles, 0 A to 3.60 A transition (3x pickup).

Time Delay = (8)

$$TMS \cdot \left[B + \frac{A}{(I_{multiple})^{p} - 1} \right] = 8 \cdot \left[0.0228 + \frac{0.0103}{(3)^{0.02} - 1} \right] = 8 \cdot \left[0.0228 + \frac{0.0103}{0.0222} \right] = 3.89\ s$$

3. End of 67 test.

67N Directional Earth Fault Test

Settings

- 67N Pickup = 1.2 A
- Alpha = 180° (This is the positive sequence current angle start point with respect to positive sequence voltage angle.)
- Beta = 180° (This is the operating "Window". In this case the 67 element should operate between [Alpha to (Alpha + Beta)] = [180° to (180° + 180°)] = 180° to 360?

  Time Curve = IEEE Moderately Inverse

  A = 0.0103

  B = 0.0228

  p = 0.02

  TMS = 8.0
- As shown in for details see Figure 7.12: Logic, Directional Overcurrent (67) on page 7-17, map elements to outputs in the Output Matrix:

  67N Pickup mapped to Out 4

  67N Trip mapped to Out 5

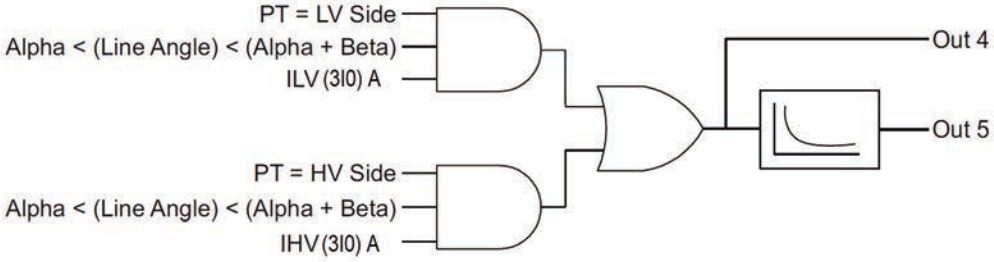


Figure 7.13: Logic, Directional Earth fault (67N)

67N Test Procedure

1. Access Relay Control Panel *Metering > Logic 1* or *Front HMI, Metering >Logic> Logic Protections 1.*
2. Monitor the following element for pickup: 67N Alarm.
3. Following are the default test quantities (future tests will refer to these default test quantities).

   Apply a single-phase current to the T-PRO terminals as follows:

   Ph A: 300 – 301, 1.0 A ∠-90°
4. Apply single-phase polarizing voltage to:

   Ph A: 330 – 333, 66.4 V ∠0°
5. Slowly ramp the 3-phase currents magnitudes up.

   At 1.15 to 1.25 A (expect 1.20 A):

   67N Alarm = High
6. Increase currents to 2.0 A.

Observe: 67N Trip = High

7. Ramp phase-A current angle in positive direction from -90°.

   At -1.0° to +1.0° (expect 0°):

   67N Alarm = Low

8. Return current angles to -90°, +150°, +30°.

9. Ramp current angle in negative direction from -90°.

   At -179° to -181° (expect -180°):

   67N Alarm = Low

10. Turn currents OFF (Keep voltage On for the timing test).

    67N Alarm = Low

67N Timing Test

1. Monitor timer stop on 67N Trip Contact (Output Contact 5 in the settings)
2. Set timer start from 3-phase currents at default angles, 0 A to 3.60 A transition (3x pickup).

Time Delay = (9)

$$TMS \cdot \left[B + \frac{A}{(I_{multiple})^{p} - 1} \right] = 8 \cdot \left[0.0228 + \frac{0.0103}{(3)^{0.02} - 1} \right] = 8 \cdot \left[0.0228 + \frac{0.0103}{0.0222} \right] = 3.89\ s$$

3. End of 67N test.

50/51 Instantaneous and Time Overcurrent 3-Phase Test

Settings

- 50HV Pickup = 1.5 per unit
- 51HV Pickup = 1.2 per unit

  Time Curve = IEEE Very Inverse

  A = 3.922

  B = 0.0982

  p = 2

  TMS = 4.0
- As shown in Figure 7.14: on page 7-21, map elements to outputs in the Output Matrix:

  50HV mapped to Out 14

  51HV Alarm mapped to Out 7

  51HV Trip mapped to Out 2

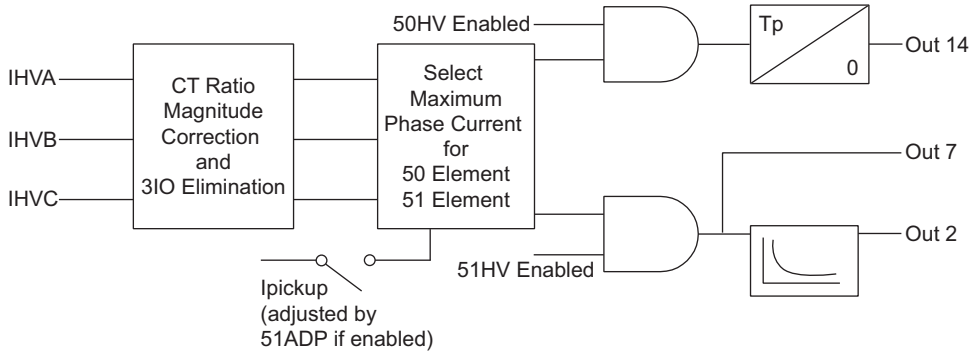


Figure 7.14: Logic, Phase Overcurrent (50/51)

50/51 3-Phase Test Procedure

1. Access Relay Control Panel *Metering* > *Logic 2* or Front HMI, *Metering* > *Logic* > *Logic Protections 2*
2. Monitor the following element for pickup: 51HV Alarm.
3. Apply balanced 3-phase currents to the T-PRO terminals as follows:

   Ph A: 300 – 301, 1.0 A ∠0°

   Ph B: 302 – 303, 1.0 A ∠−120°

   Ph C: 304 – 305, 1.0 A ∠+120°
4. Slowly ramp the 3-phase currents up.

   At 1.15 to 1.25 A (expect 1.20 A):

   51 Alarm = High
5. Continue to raise currents.

   At 1.45 to 1.55 A (expect 1.50 A):

   50 Trip = High
6. Turn currents off.

51 Alarm = Low

50 Trip = Low

51HV Timing Test

1. Monitor timer stop on 51HV Trip Contact *(Output Contact 2 in the settings)*.
2. Set timer start from 3-phase 0.0 A to 3.60 A transition (This equates to 3x pickup.).

Time Delay =

$$TMS = \left[B + \frac{A}{(I_{multiple})^p - 1}\right] = 4 \times \left[0.0982 + \frac{3.922}{3^2 - 1}\right] = 4 \times \left[0.0982 + \frac{3.922}{8}\right] = 2.35s \quad (10)$$

3. End of 50HV 51HV test

51ADP Adaptive Pickup Test

Settings

- Nameplate: Cooling: Type 1, Self-Cooled OA or OW
- Ambient Temperature Scaling: 4 mAdc = -40°C, 20 mAdc = +40°C
- 51ADP Multiple of Normal Loss of Life = 1.0

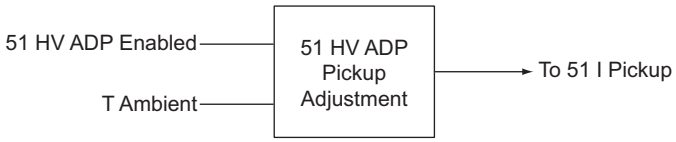


Figure 7.15: Logic Overcurrent Adaptive Pickup (51ADP)

51ADP Test Procedure

To simulate an ambient temperature of +30°C, inject 18.0 milliamps dc into the Ambient Temperature Input (terminals +230, -231).

In Relay Control Panel *Metering > Trend,D49 > Ambient Temp* or Front HMI, access *Metering>Analog>Trend>Ambient Temp,* confirm a +30°C reading.

Using the graph : Figure M.3: Allowed Loading: 65°C Rise Transformer, Type 1 Cooling on page M-4 (Appendix M), see that at +30°C the overload characteristic is de-rated to 1.0 per unit for a relative loss of life setting of 1.0.

1. Access Relay Control Panel *Metering>Logic* or Front HMI, *Metering>Logic>Logic Protections 3.*
2. Monitor the following element for pickup: 51HV Alarm.
3. Apply balanced 3-phase currents to the T-PRO terminals as follows:

   Ph A: 300 – 301, 0.8A ∠0°

   Ph B: 302 – 303, 0.8A ∠-120°

   Ph C: 304 – 305, 0.8A ∠+120°

4. Slowly ramp the 3-phase currents up.
   At 0.95 to 1.05 A (expect 1.0 A):
   51 Alarm = High
5. Turn currents off.
   51 Alarm = Low
6. End of 51ADP test.

Checking Ambient Temperature Alarm

1. Access Relay Control Panel *Metering>Logic 1* or Front HMI, *Metering>Logic>Logic Protections 1.*
2. Monitor for pickup:
   Ambient Alarm.
3. With 18 mA being injected into Ambient Temperature input:
   Ambient Alarm = Low

Note: The Ambient Temperature Alarm will activate if the Ambient Temperature is outside of the Setting Range.

4. Slowly ramp the mA input up from 18 mA.
   At Approximately 21 mA:
   Ambient Alarm = High
5. Remove mA input from Ambient Temperature input.
   Ambient Alarm = High (since 0mA is out of the setting range)
6. End of Ambient Alarm test.

Checking the Top Oil Temperature Alarm

Switch mAdc from Ambient Temperature input to Top Oil Temperature input (terminals +232, -233).

Top Oil Settings

- Top Oil Temperature Scaling: 4.0 mAdc = -40°C and 20.0 mAdc = +200°C

To simulate a Top Oil Temperature of +170°C, inject 18.0 mAdc into the Top Oil Temperature Input (+232, -233).
In Relay Control Panel or Front HMI, access *Metering>Analog>Trend>Top Oil Temp DegC,* confirm a +170°C reading.

Top Oil Alarm Test

1. Access Relay Control Panel *Metering>Logic 1* or Front HMI, *Metering>Logic>Logic Protections 1.*
2. Monitor for pickup:
   Top Oil Alarm.
3. With 18 mA being injected into Top Oil Temperature input:
   Top Oil Alarm = Low
4. Ramp mA input up from 18 mA.
   At approximately 21 mA:
   TopOil Alarm = High

5. Remove mA input from Top Oil Temperature input.

   Top Oil Alarm = High (since 0 mA is out of the setting range)

6. End of Top Oil Alarm test.

49 Thermal Overload Test

Prepare to inject dc milliamps into Top Oil Temperature input (+232 – 233)

Settings

- 49 HV = 1.2 per unit
- Hysteresis = 0.1 per unit

and

- Top Oil Temperature = 160°C
- Temperature Hysteresis = 1.0°C
- As shown in Figure 7.27: on page 7-34, map elements to outputs in the Output Matrix:

  49_Trip mapped to Out 12

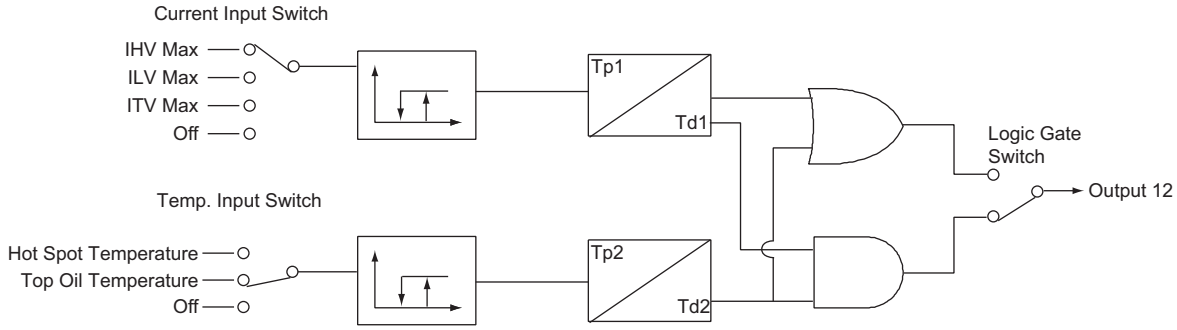


Figure 7.16: Logic, Thermal Overload (49)

1. Access Relay Control Panel *Metering>Logic 1* or Front HMI, *Metering>Logic>Logic Protections 1*.
2. Monitor for pickup:

   49_1 Trip

3. Inject 18 mAdc into Top Oil Temperature input (160°C setting is exceeded)

   and

   Inject 3-phase currents into:

   Ph A: 300 – 301, 1.0 A ∠0°

   Ph B: 302 – 303, 1.0 A ∠-120°

   Ph C: 304 – 305, 1.0 A ∠+120°

   Observe:

   49_1 Trip = Low

4. Ramp current up.

   At 1.15 to 1.25 A (expect 1.20 A):

   49_1 Trip asserts

5. Decrease Top Oil Temperature to 16 mA.

   49_1 Trip De-asserts

6. Ramp Top Oil Temperature input up to 17.0 to 17.6 mA

   49_1 Trip Asserts

7. Remove:

   mA from Top Oil Temperature input

   Currents from HV input

8. End of 49 test.

49 TOEWS Test

The Transformer Overload Early Warning System warns and trips for conditions of either excessive hot spot temperature or excessive loss of life during any single overloading occurrence.

Settings

- Transformer MVA: 100
- Transformer Cooling Method: Self cooled
- Transformer Temperature Rise: 65°C
- Normal Loss of Life Hot Spot Temperature: 110°C
- THS Trip Setting: 150°C
- THS to start LOL Calculation:150°C
- LOL Trip Setting: 1 day
- Top Oil : Calculated
- As shown in Figure 7.17: on page 7-25, map elements to outputs in the Output Matrix:

  TOEWS Trip mapped to Out 11

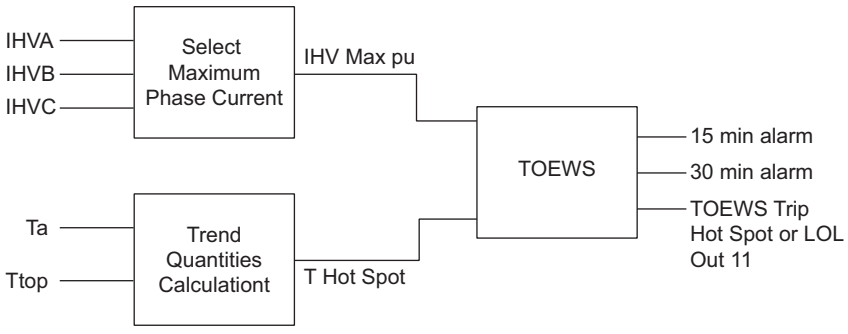


Figure 7.17: Logic, Transformer Overload Early Warning System (49TOEWS)

TOEWS Test Procedure

1. Apply balanced 3-phase currents to the T-PRO terminals as follows:

   Ph A: 300 – 301, 1.00 A ∠0°

   Ph B: 302 – 303, 1.00 A ∠-120°

   Ph C: 304 – 305, 1.00 A ∠+120°

2. Apply 16 mAdc (20°C) to Ambient Temperature input terminals +230, -231.

   Re-boot the T-PRO (cycle power) to reset the steady state condition, otherwise the T-PRO only assumes a new steady state after hours of "settling in". (Note: When the T-PRO is installed, this is not a problem and is the correct way to respond.)

3. Access Relay Control Panel *Metering>Logic 1* or Front HMI, *Metering>Logic>Logic Protections 1.*

4. Monitor the following elements for pickup.

   TOEWS 30min Alarm

   TOEWS 15min Alarm

   TOEWS Trip = Low

   Observe:

   HV current = 1.00 per unit (as per current being injected at step 1).

   Ambient Temperature = 20°C, Top Oil Temperature = 75°C, Hot Spot Temperature = 100°C.

5. Increase current to simulate an overload condition (e.g. 180% Load).

   Over a period of time (hours) observe, in order:

   30 min Alarm = High

   15 minutes later: 15 min Alarm = High

   15 minutes later: TOEWS Trip = High

Hint: If you set the T-PRO to trigger a recording on each of these events, you can ensure that you will retain records of when these elements operate.

Checking the warning and trip times can only be properly done by comparing "heat runs" made on software (an MS Excel spreadsheet) available from ERLPhase. Very stable temperature mA inputs and current inputs over a period of hours are necessary to get predictable and satisfactory timing test results.

6. End of TOEWS test.

59 Overvoltage Functional Test

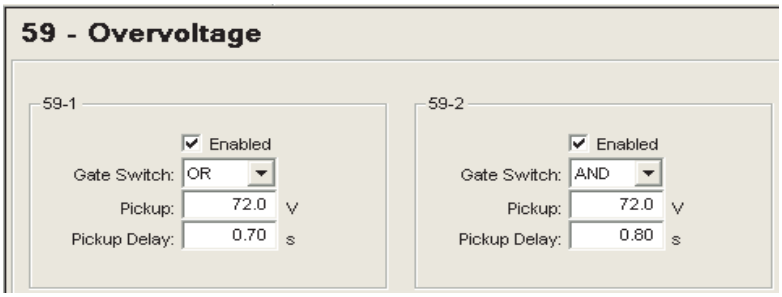


Figure 7.18: 59 Functional Test Settings

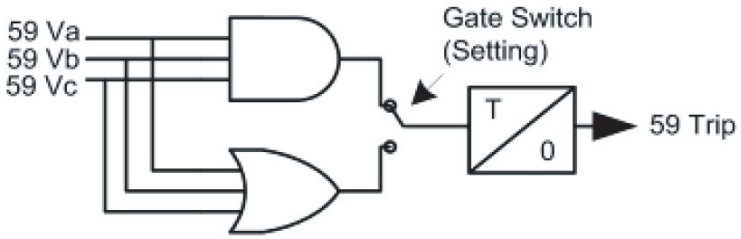


Figure 7.19: Overvoltage Functional Test Settings and Logic, mapped to Output 17

59 Test Procedure

1. In Relay Control Panel access relay access *Metering>Logic 2*

   Monitor the following elements for pickup.

   59-1 Trip

   59-2 Trip

   Monitor contacts.

   Output: 17

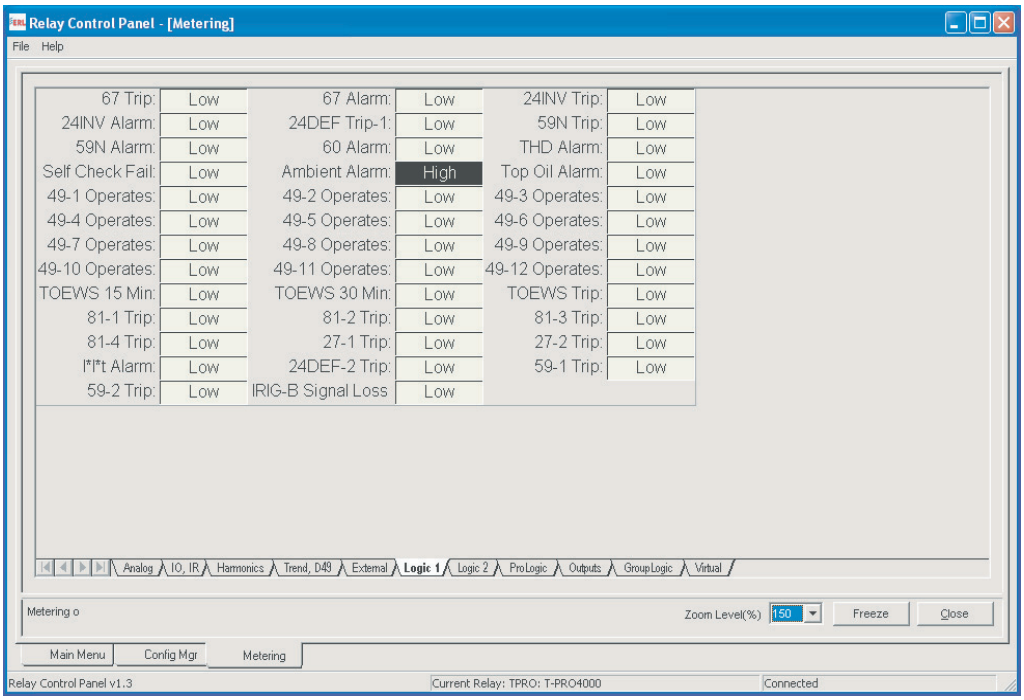


Figure 7.20: 59 Functional Test Settings

2. Apply balanced 3-phase nominal voltages (66.4 V) to the T-PRO terminals.

   Ph A: 330, 66.4V ∠ 0°

   Ph B: 331, 66.4V ∠ -120°

   Ph C: 332, 66.4V ∠ +120°

   Ph N: 333

   Observe: 59-1 Trip = Low

   59-2 Trip = Low

3. Increase A-phase voltage:

   At 70.0 to 74.0 V (expect 72 V):

   Observe: 59-1 Trip = High

   Out 3 = Closed

   Observe: 59-2 Trip remains low

   Out 4 = Open

4. With A-phase voltage still at about 72 V, increase both B- and C-phase voltages:

   At 70 to 74 V (expect 72 V):

   Observe: 59-1 Trip = High

   Observe: 59-2 Trip = High

   Out 4 = Closed

End of 59 test.

50BF Functional Test

External Input Method/Current Detection Method

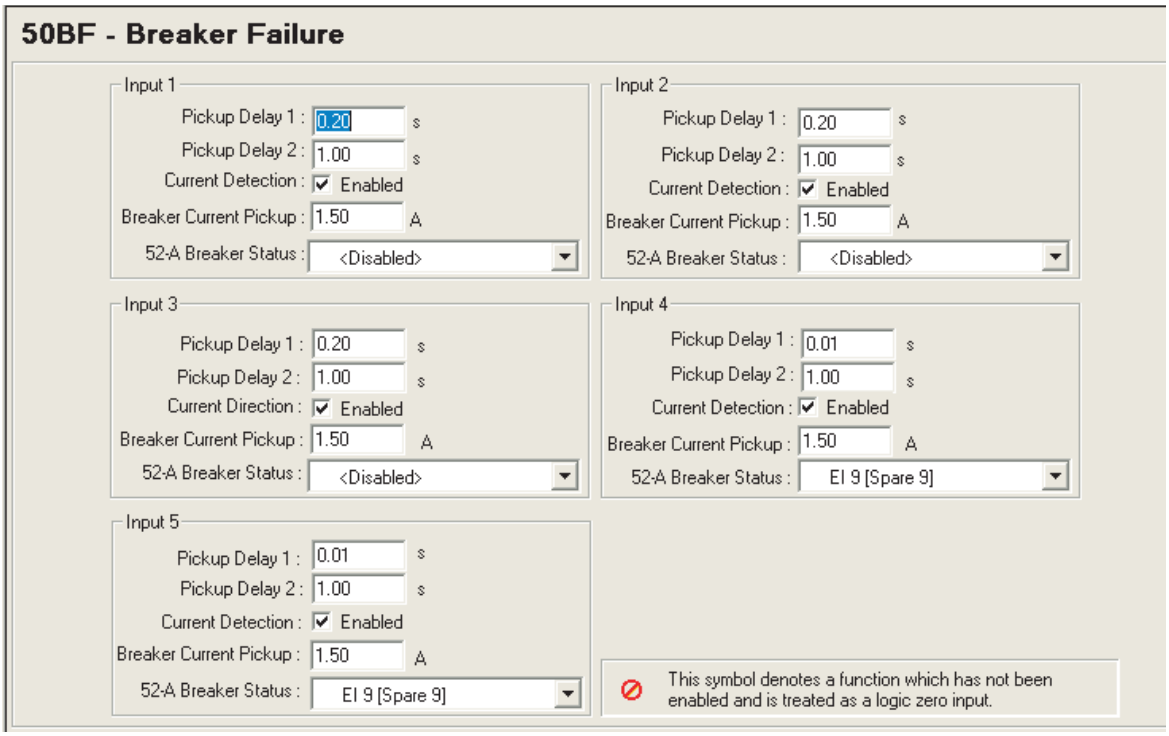

50BF - Breaker Failure
Input 1
Pickup Delay 1 : 0.20 s
Pickup Delay 2 : 1.00 s
Current Detection : Enabled
Breaker Current Pickup : 1.50 A
52-A Breaker Status : <Disabled>
Input 2
Pickup Delay 1 : 0.20 s
Pickup Delay 2 : 1.00 s
Current Detection : Enabled
Breaker Current Pickup : 1.50 A
52-A Breaker Status : <Disabled>
Input 3
Pickup Delay 1 : 0.20 s
Pickup Delay 2 : 1.00 s
Current Direction : Enabled
Breaker Current Pickup : 1.50 A
52-A Breaker Status : <Disabled>
Input 4
Pickup Delay 1 : 0.01 s
Pickup Delay 2 : 1.00 s
Current Detection : Enabled
Breaker Current Pickup : 1.50 A
52-A Breaker Status : EI 9 [Spare 9]
Input 5
Pickup Delay 1 : 0.01 s
Pickup Delay 2 : 1.00 s
Current Detection : Enabled
Breaker Current Pickup : 1.50 A
52-A Breaker Status : EI 9 [Spare 9]
This symbol denotes a function which has not been enabled and is treated as a logic zero input.

Figure 7.21: 50BF Functional Test Settings

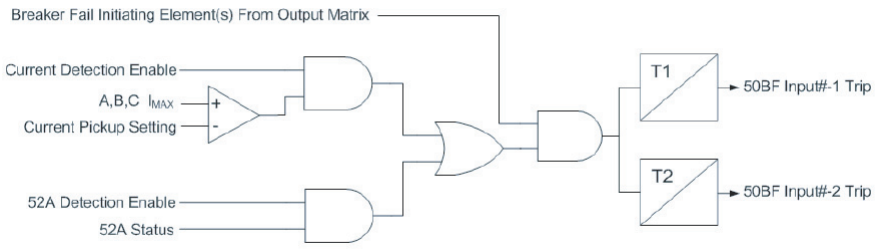


Figure 7.22: 50BF Breaker Fail Functional Test Settings and Logic, Mapped to Output 15

Note: Requires a minimum of 1.5 A on any phase to arm the Breaker Fail.

50BF Test Procedure

1. In Relay Control Panel access *Metering* > *Outputs*.
   Monitor normally open Out 15 (50BF).

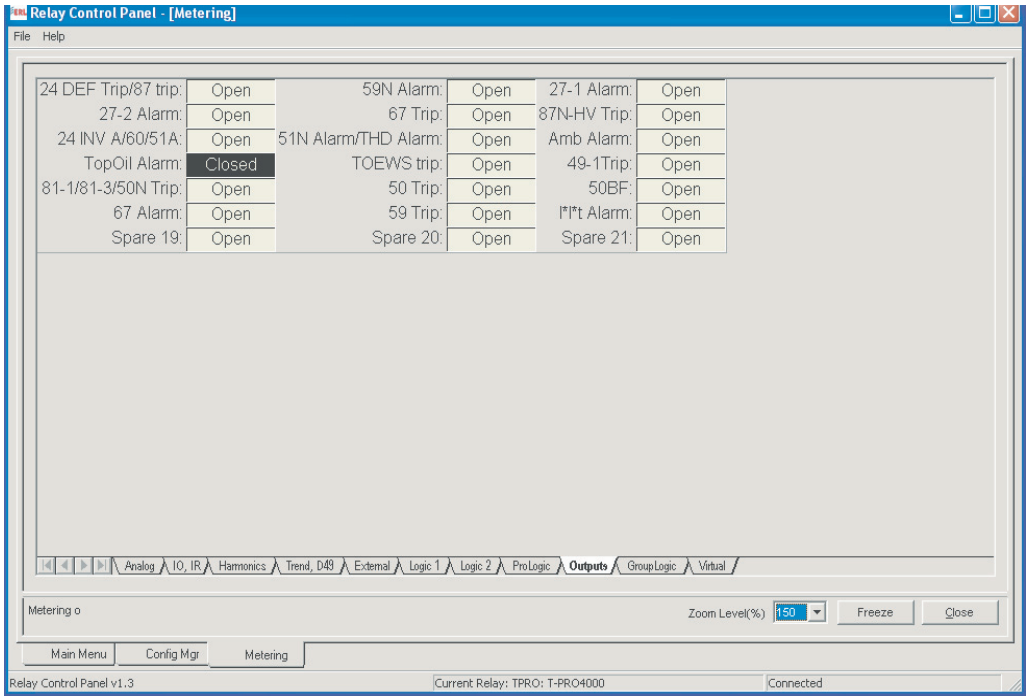


Figure 7.23: Output Contacts

2. Enable all winding connections as follows:

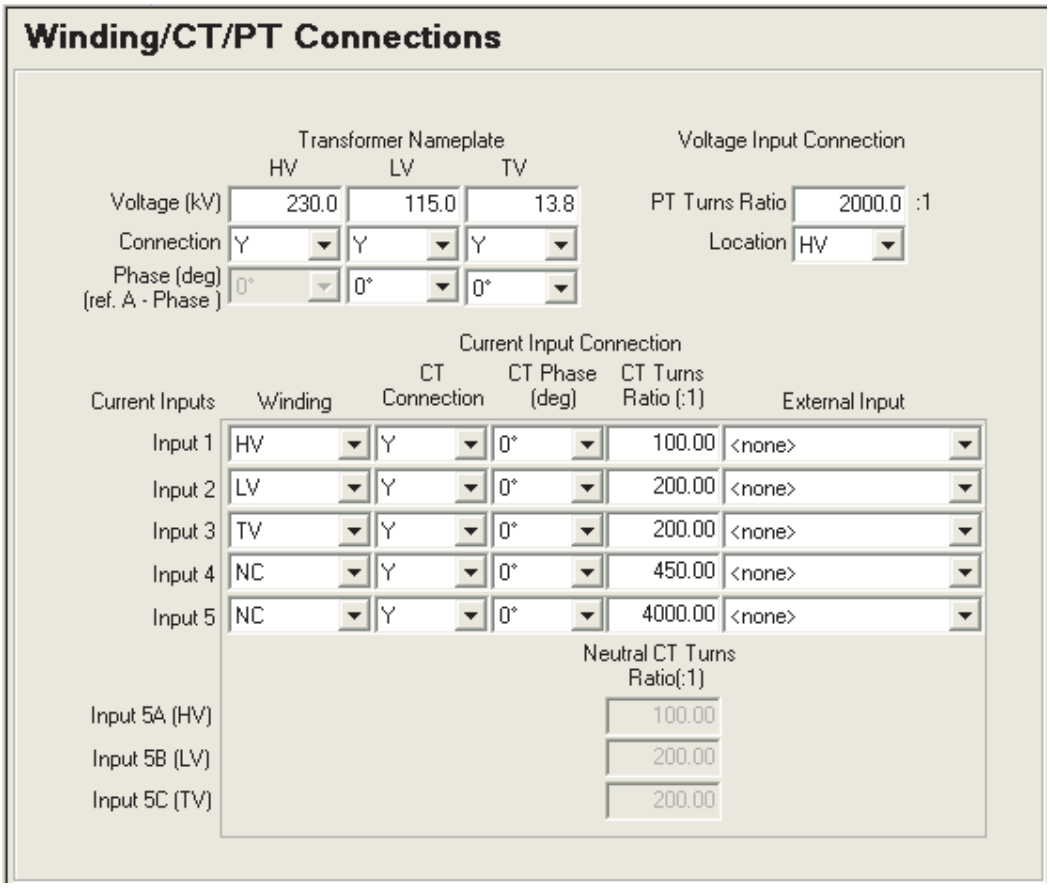


Figure 7.24: Current Input and Winding Connections

3. Enable 59 Overvoltage protection for fault and breaker failure initiation.

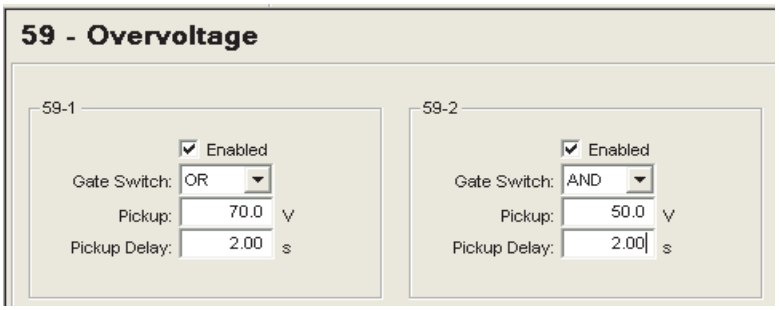


Figure 7.25: 59 Functional Settings

4. Assign protection functions to output contacts, to initiate breaker fail, initiate trigger fault recording and to illuminate target LEDs.

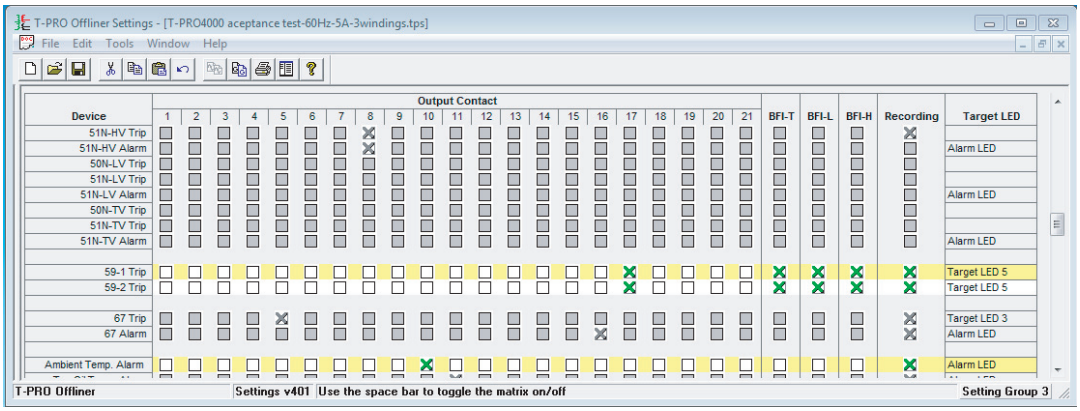


Figure 7.26: Output Matrix

> Note: BFI-LV should be selected for LV winding input 4 and BFI-TV winding input 5.

5. Inject main voltage to the T-PRO terminal as follows:

   V: 330 – 333 = 70 V (to operate 59-1 trip for fault and breaker failure initiation)

   Observe: 59 overvoltage = High

   Out 17: Closed

Current Detection Method

6. Apply single-phase current to T-PRO Input 1, Input 2, Input 3, Input 4 and Input 5 as follows:

   PhI1A: 300 – 301 = 1.5 A

   PhI2A: 306 – 307 = 1.5 A

   PhI3A: 312 – 313 = 1.5 A

   PhI4A: 318 – 319 = 1.5 A

   PhI5A: 324 – 325 = 1.5 A

   Observe:

   Input 1 Trip 1 50BF = High

   Input 1 Trip 2 50BF = High

   Input 2 Trip 1 50BF = High

   Input 2 Trip 2 50BF = High

   Input 3 Trip 1 50BF = High

   Input 3 Trip 2 50BF = High

   Input 4 Trip 1 50BF = High

   Input 4 Trip 2 50BF = High

   Input 5 Trip 1 50BF = High

Input 5 Trip 2 50BF = High

Out 15 = Closed

7. Turn current off.

Observe: 50BF elements = Low

Observe: Output 15 = Open

External Input Method

8. Make External Input 9 High:

Observe:

Input 4 Trip 1 50BF = High

Input 4 Trip 2 50BF = High

Input 5 Trip 1 50BF = High

Input 5 Trip 2 50BF = High

External Input 9 = High

Out 15: Closed

9. Turn voltage and External Input 9 off.

Observe:

50BF Elements = Low

External Input 9 = Low

Out 15: Open

End of Breaker Fail test.

87 Differential Test

This section covers the testing of the 87 minimum operating point IO_{min}. Generally this is the only test that is required to prove the minimum sensitivity of the differential element. The IO_{min} test proves the Nameplate Rating, the KV, CT Ratio and IO_{min} settings are all correct.

If more comprehensive and complex testing is desired, you may skip this 87 Differential Test section and go to section “T-PRO 3-Phase 87 High Mismatch Slope Testing” on page 7-45 instead.

Settings

- MVA: 100
- Windings: 2
- HV kV: 230 (Y 0°)
- LV kV: 115 (Delta -30°)
- HV CT: 250:1 (Y 0°)
- LV CT: 500:1 (Y 0°)
- PT Location: High Side
- IOmin: 0.3 per unit
- IRs: 5.0 per unit

- Slope 1: 20%
- Slope 2: 40%
- As shown in Figure 7.27: on page 7-34, map elements to outputs in the Output Matrix:

  87 Trip mapped to Out 1

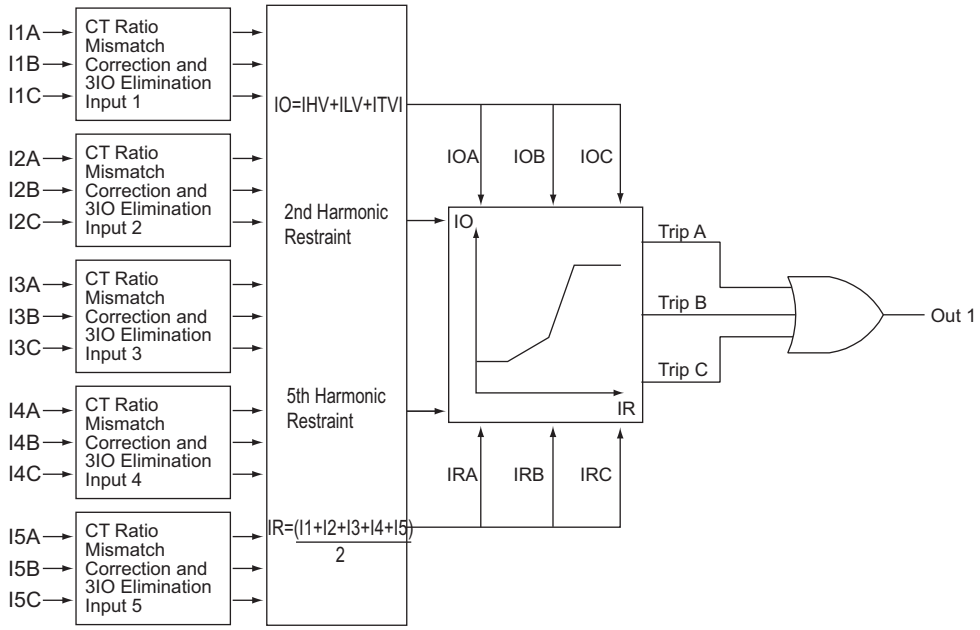


Figure 7.27: Logic, Phase Differential (87)

Magnitude Mismatch Correction Factor (MMCF)

Calculation shown on “3. Magnitude Mismatch Corrections” on page 4-7

$$Magnitude\_Mismatch\_Correction\_Factor[i] = \frac{PhysicalCT\_Root3\_Factor[i] \times Voltage\_Level[i] \times CT\_Ratio[i]}{PhysicalCT\_Root3[REF] \times Voltage[REF] \times CT\_Ratio[REF]} \quad (11)$$

$$Magnitude\_Mismatch\_Correction\_Factor[i] = \frac{1.0 \times 115 \times 500}{1.0 \times 230 \times 250} = 1.0$$

Where

i = Current input being considered (in this case LV side).

PhysicalCT_Root3_Factor = 1.0 for a Y connected CT, 1/3 for Delta connected CT.

Voltage_Level[i] = Voltage level of the input being considered

CT_Ratio[i] = CT ratio of the input being considered.

Voltage[REF] = Primary voltage level of the reference (PT) side (in this case HV side).

CT_Ratio[REF]= CT ratio of the first current input on the reference (PT) side.

Secondary base current [REF] = (12)

$$\frac{1000 \times MVA}{\sqrt{3} \times kV_{HV}} \times \frac{1}{CTR_{HV}} = \frac{1000 \times 100}{\sqrt{3} \times 230} \times \frac{1}{250} = 1.00A$$

Secondary base current [i] = Secondary Base Current [REF]MMCF[i] = 1.00A

Therefore:

HV Secondary Base = 1.00 A

LV Secondary Base = 1.00 A

HV Minimum Operate = IO_{min} x HV Secondary Base = 0.3 x 1.00 A = 0.30 A

LV Minimum Operate= IO_{min} x LV Secondary Base = 0.3 x 1.00 A = 0.30 A

87 HV 3 Phase Minimum Operate Test Procedure

1. Access Relay Control Panel *Metering > Logic 2* or Front HMI, *Metering > Logic > Logic Protections 2*.
2. Monitor the following element for pickup: 87 Trip.
3. Prepare to apply balanced 3-phase currents to the T-PRO terminals as follows:

   Ph A: 300 – 301, ∠0

   Ph B: 302 – 303, ∠-120

   Ph C: 304 – 305, ∠+120
4. Simultaneously and slowly ramp all 3 currents up:

   At 0.29 to 0.31 A (expect 0.30 A):

   87 Trip = High
5. Run the same test on the LV side.

   Since MMCF is 1.0, LV pickup will be the same as the HV pickup = 0.30 A.
6. End of 3-Phase Minimum Operate test.

Single-Phase Test of 87 HV Minimum Operate

To test the 87 single-phase, an additional Correction must be applied to compensate for the T-PRO zero sequence elimination. To eliminate zero sequence and normalize the current angles of all inputs, the T-PRO uses the formulas in the “Current Phase Correction Table” in Appendix L.

T-PRO is a 3-phase relay, but will operate on a phase-by-phase basis. When the differential setting is exceeded on any one phase or more, the 87 element will operate.

For simplicity, calculate how much current each phase of the T-PRO will see by using 1.0 A as a base in the formulas of CPC. The result gives a ratio that is valid for any magnitude of current applied.

The HV Side in the our test settings has HV net shift of 0°:

HVNet Shift = HV Winding Shift (0°) + HV CT Shift (0°) = 0° + 0° = 0°

The 0° connection is compensated by 360° (i.e., CPC12 of "Loss of Life of Solid Insulation" in Appendix M). Not that there is a formula for each phase A, B and C.

If you inject 1.0 A on Phase A only on the HV side, the following equations of CPC12 show how much current the T-PRO will see on all 3 phases.

$$IA = \frac{2Ia - Ib - Ic}{3} = \frac{2(1) - (0) - (0)}{3} = \frac{2}{3}A \quad (13)$$

$$IB = \frac{2Ib - Ic - Ia}{3} = \frac{2(0) - (0) - (1)}{3} = \frac{-1}{3}A \quad (14)$$

$$IC = \frac{2Ic - Ia - Ib}{3} = \frac{2(0) - (1) - (0)}{3} = \frac{-1}{3}A \quad (15)$$

The current per unit values can be confirmed in Relay Control Panel *Metering>Analog* or Front HMI *Metering>Analog>Analog Inputs 2*.

Note that the strongest phase in this case is IA, so as you ramp up the current above the IO_{min} setting, expect that IA will operate first. We can disregard the weaker phases in the context of the IO_{min} test.

From the 3-phase test section note that IO_{min} = 0.30 A.

Since the relay sees only 2/3 of the injected current on the strongest phase, the single phase correction factor in this case is 1/(2/3) = 1.5.

That is, for the T-PRO to see 0.30 A on the single operating phase A, inject 0.30 A x 1.5 = 0.45 A.

HV 87 IO_{min} Single-Phase Test Procedure

1. Access Relay Control Panel *Metering > Logic 2* or Front HMI, *Metering > Logic > Logic Protections 2*.
2. Monitor the following element for pickup:

   87 Trip.
3. Connect current source to T-PRO terminals 300 – 301.

   Slowly ramp the current up.

At 0.44 to 0.46 A (expect 0.45 A):

87 Trip = High

4. Turn current off.

87 Trip = Low

5. End of HV 87 IO_{min} Single-Phase Test

Testing 87 LV Minimum Operate Single-Phase

To test single-phase, perform the same process as on the HV side, again use "Current Phase Correction Table" in Appendix L.

The HV Side in the our test settings has HV net Shift of 0°:

HVNet Shift = HV Winding Shift (0°) + HV CT Shift (0°) = 0° + 0° = 0°

The LV Side in our test settings has LV net Shift of -30°:

LV Net Shift = LV Winding Shift (-30) + LV CT Angle (0°) = -30° + 0° = -30°

The -30° angle must be corrected to be 0°, therefore find the +30° compensation in CPC. There is an equation for each of A, B and C phases. If you inject 1.0 A on Phase A only on the LV side, the following equations show how much current the relay will see on all 3 phases.

If you inject 1.0 A in LV side Phase A only:

$$IA = \frac{Ia - Ib}{\sqrt{3}} = \frac{(1) - (0)}{\sqrt{3}} = \frac{1}{\sqrt{3}} = 0.577A \quad (16)$$

$$IB = \frac{Ib - Ic}{\sqrt{3}} = \frac{(0) - (0)}{\sqrt{3}} = \frac{0}{\sqrt{3}} = 0A \quad (17)$$

$$IC = \frac{Ic - Ia}{\sqrt{3}} = \frac{(0) - (1)}{\sqrt{3}} = \frac{-1}{\sqrt{3}} = -0.577A \quad (18)$$

Note that the strongest phases are IA and IC, so they will operate first (IB in this case sees no current and can be disregarded in the context of this test).

Since the relay sees only 0.577 times the injected current on the strongest phase (s), the single phase correction factor in this case is 1/(0.577) = 1.73. That is, for the T-PRO to see 0.30 A on the operating phase, you need to inject 0.30 A x 1.73 = 0.52 A

LV 87 IO_{min} Single-Phase Test Procedure

1. Access Relay Control Panel *Metering* > *Logic 2* or Front HMI, *Metering* > *Logic* > *Logic Protections 2*.
2. Monitor the following element for pickup:

   87 Trip.
3. Connect current source to T-PRO terminals 306 – 307.

   Slowly ramp the current up.

   At 0.51 to 0.53 A (expect 0.52 A):

   87 Trip = High
4. Turn current off.

   87 Trip = Low
5. End of LV 87 IO_{min} Single-Phase Test

87 2nd Harmonic Restraint Test

Settings

- I2 Cross Blocking = Enabled
- I2 (2nd Harmonic) = 0.20 per unit (2nd Harmonic Restraint if ≥ 20% of fundamental current).

2nd Harmonic Restraint Test Procedure

1. Access Relay Control Panel *Metering* > *Logic 2* or Front HMI, *Metering* > *Logic* > *Logic Protections 2*.
2. Monitor for pickup:

   87 Trip

   87 Restraint
3. Apply parallel currents to Terminals 300 – 302 (Jumper 301 – 303) as follows:

   Source 1 (60 Hz): 1.0 A ∠0° (Terminals 300 – 302)

   Source 2 (120 Hz): 0.40 A ∠0° (paralleled with Source 1 into Terminals 300 – 302)

   Observe:

   87 TRIP = Low

   87 Restraint = High
4. Slowly ramp down Source 2.

   At Source 2 = 0.19 to 0.21 A (expect 0.20 A):

   87 Trip = High

   87 Restraint = Low
5. End of 2nd harmonic restraint test.

87 High Current Setting Test

Settings

- High Current Setting = 5.0 per unit

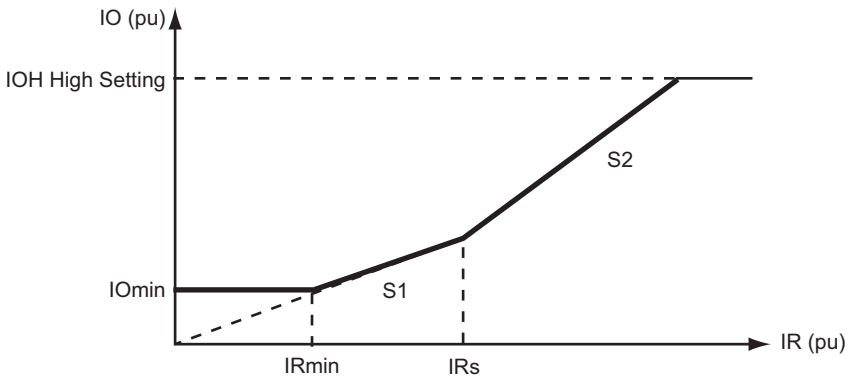


Figure 7.28: IOH High Current Setting

87 High Current Test Procedure

This test proves that when the High Current Setting is exceeded, the 87 will operate and 2nd Harmonic has no restraint affect.

1. Access Relay Control Panel *Metering* > *Logic 2* or Front HMI, *Metering* > *Logic* > *Logic Protections 2*.
2. Monitor for pickup:
   87 Restraint
   87 Unrestrained Zone
3. Apply parallel currents to Terminals 300 – 302 as follows (Jumper 301 – 303):
   Source 1 (Fundamental, 60 Hz):
   4.0 A ∠0° (Terminals 300 – 302)
   Source 2 (2^{nd} Harmonic, 120 Hz):
   4.0 A ∠0° (also Terminals 300 – 302)
4. Ramp Source 1 (fundamental) up:
   At 4.90 to 5.10 A (expect 5.0 A):
   87 Restraint = High
   87 Unrestrained Zone = High
5. Remove test currents.
6. End of 87 High Current Test

THD Alarm Test

Settings

- THD Alarm Pickup: 10%
- As shown in Figure 7.29: on page 7-40, map the THD Alarm to Out 8 in the Output Matrix

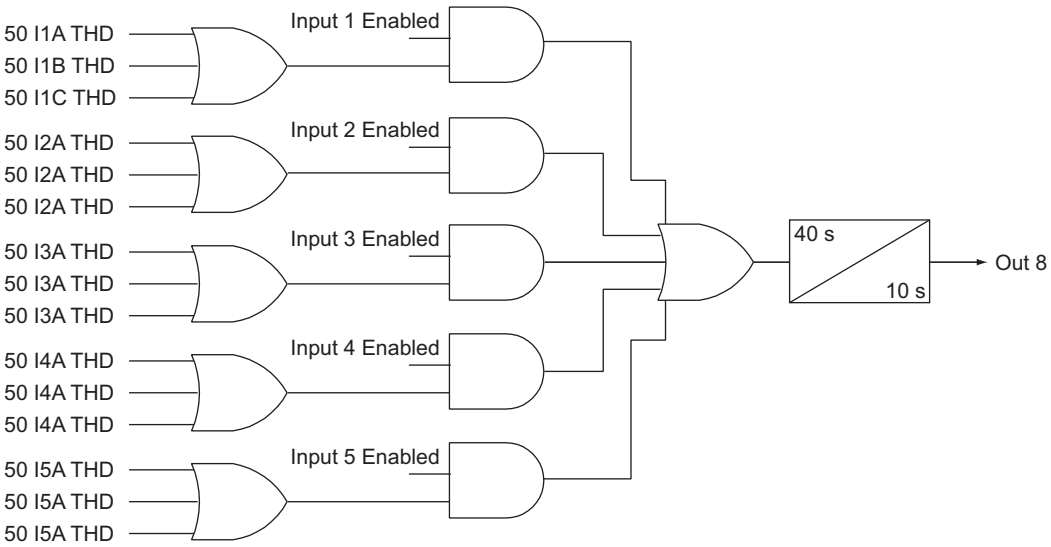


Figure 7.29: Logic, Total Harmonic Distortion Alarm (THD)

For testing THD, use the fundamental with one harmonic from 2^{nd} to 25^{th} . In this case the T-PRO uses the following formula for calculating Total Harmonic Distortion:

(19)

$$THDpercent = 100 \cdot \frac{\sqrt{\sum_{2}^{25} I^2 n}}{Ifundamental} = \left(100 \cdot \frac{\sqrt{Iharmonic^2}}{Ifundamental}\right) = \left(100 \cdot \frac{Iharmonic}{Ifundamental}\right)$$

THD Test Procedure

1. Access Relay Control Panel *Metering>Logic 1* or Front HMI, *Metering>Logic>Logic Protections 1.*
2. Monitor the following element for pickup: THD Alarm.
3. Apply parallel currents to terminals 300 – 301 as follows:

   Source 1 (Fundamental 60 Hz): 2.0 A ∠0° (Terminals 300 – 301)

   Source 2 (2^{nd} Harmonic 120 Hz): 0.0 A ∠0° (also Terminals 300 – 301)
4. Slowly ramp Source 2 up to 0.21 A

   Monitor the THD (Metering) above 10%

After 30 seconds

THD Alarm = High

Contact 8 = Closed

End of THD test.

87N Neutral Differential Test

Testing the 87N uses the same process as testing the 87 with the following exception: I5A is used for the neutral associated with HV wye connected winding (I5B for LV, I5C for tertiary).

Settings

- MVA = 100
- HV kV: 230 kV
- IO_{min}: 0.3 per unit
- IRs: 5.0 per unit
- Slope 1: 20%
- Slope 2: 40%
- HV CT Ratio: 250:1
- Neutral CT Ratio: 100:1

As shown in Figure 7.30: on page 7-41, map the 87N HV Trip to Out 6 in the Output Matrix.

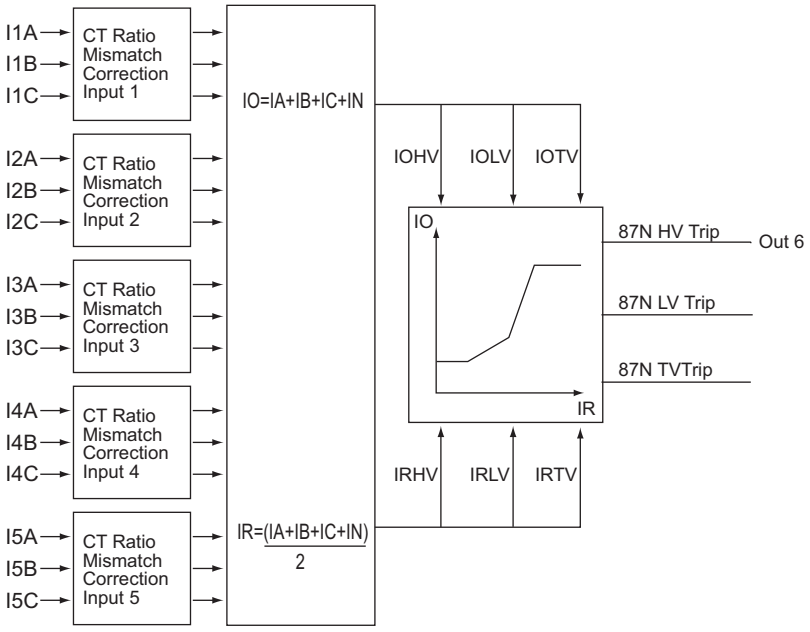


Figure 7.30: Logic, Neutral Differential (87N)

87N MCF Calculation

$$MagnitudeCorrectionFactor(MCF) = \frac{PhaseCTRatio}{NeutralCTRatio} = \frac{250}{100} = 2.50 \quad (20)$$

Phase Winding 87N IOmin Pickup Calculation

Expect:

$$IO\min = \frac{kVA}{\sqrt{3} \times kV} \times \frac{1}{CTR} \times IO\min PerUnit = \left(\left(\frac{100e3}{\sqrt{3} \times 230} \times \frac{1}{250} \right) \times 0.3 \right) = 0.30A \quad (21)$$

Neutral Winding 87N IO_{min} Pickup Calculation

Expect for I5A HV winding side

$$IO\min = \frac{kVA}{\sqrt{3} \times kV} \times \frac{1}{CTR} \times IO\min PerUnit = \left(\left(\frac{100e3}{\sqrt{3} \times 230} \times \frac{1}{100} \right) \times 0.3 \right) = 0.753A \quad (22)$$

> Note: Repeat previous calculation for LV and TV winding side and remember I5B (326-327) should be selected for LV winding and I5C (328-329) for TV winding inputs.

87N IOmin Neutral Test Procedure

1. Connect current source to T-PRO Terminals 324 – 325.
   (I5A HV)
2. Slowly ramp current up.
   At 0.74 to 0.77 A (expect 0.753 A):
   87N-HV Trip = High
3. Turn current off.
4. End of 87N test.

7.5 T-PRO Differential Slope Test Example

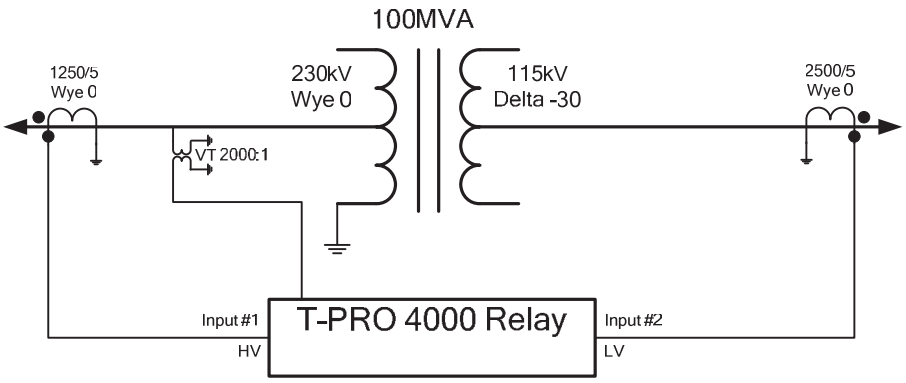


Figure 7.31: T-PRO Differential Slope Test Example

Testing T-PRO Transformer Relay 87 Relay Differential Element

Settings for the 87 differential element:

- IO_{min} = 0.3 per unit
- IRS = 5.0 per unit
- S1 = 20%
- S2 = 40%

Calculations to be performed prior to T-PRO testing:

Establish base load current for transformer reference side (i.e., side where the VT is located). For this example the VT is located on the 230 kV HV side winding.

$$I_{BasePri} = \frac{KVA}{\sqrt{3} \times kV} \quad (22)$$

$$I_{?VBaseSec} = I_{?VBasePri} \times CT_{DeltaFactor} \times \frac{1}{CTRatio} \quad (23)$$

Equation Notes:

- "?" = "H", "L" or "T" depending on the winding on which the base is being calculated.
- "Delta factor" = 1.0 for wye connected CTs, √3 for delta connected CTs.

We start with determining the base quantities, which will give us the 3-phase secondary currents at transformer nominal load. Figure 7.32: on page 7-44

shows a summary of the process used to calculate the nominal base currents from Equations (22) on page 7-43 and (23) on page 7-43.

In our example, the secondary base current on each side of the transformer = 1.004 A.

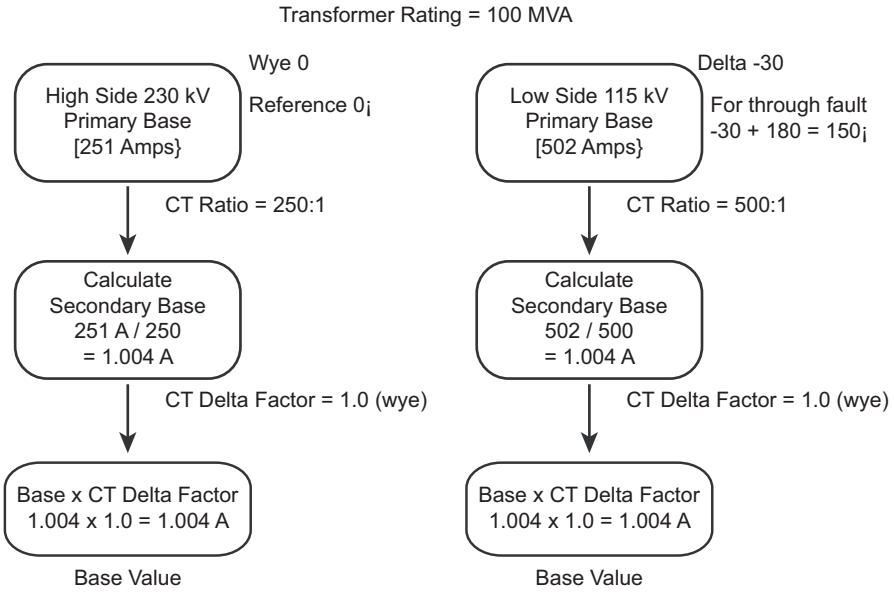

Transformer Rating = 100 MVA
Wye 0
High Side 230 kV Primary Base [251 Amps}
Reference 0¡
CT Ratio = 250:1
Calculate Secondary Base 251 A / 250 = 1.004 A
CT Delta Factor = 1.0 (wye)
Base x CT Delta Factor 1.004 x 1.0 = 1.004 A
Base Value
Delta -30
Low Side 115 kV Primary Base [502 Amps}
For through fault -30 + 180 = 150¡
CT Ratio = 500:1
Calculate Secondary Base 502 / 500 = 1.004 A
CT Delta Factor = 1.0 (wye)
Base x CT Delta Factor 1.004 x 1.0 = 1.004 A
Base Value

Figure 7.32: Summary of Calculations for Nominal Load Condition

Base Current Calculation Details for Each Winding Using Equations (22) and (23) on page 7-43.

High Voltage Side:

$$I_{BasePri} = \frac{KVA}{\sqrt{3} \times 230} = \frac{100000}{\sqrt{3} \times 230} = 251A \quad (24)$$

The primary base currents are converted to secondary amps for testing the relay.

$$I_{HVBaseSec} = I_{HVBasePri} \times CT_{DeltaFactor} \times \frac{1}{CTRatio} \quad (25)$$

$$= 251 \times 1.0 \times \frac{1}{250} = 1.004A$$

Low Voltage Side:

$$I_{BasePri} = \frac{KVA}{\sqrt{3} \times kV} = \frac{100000}{\sqrt{3} \times 115} = 502A \quad (26)$$

$$I_{LVBasePri} = I_{LVBasePri} \times CT_{DeltaFactor} \times \frac{1}{CTRatio} \quad (27)$$

$$= 502 \times 1.0 \times \frac{1}{500} = 1.004A$$

T-PRO 3-Phase 87 High Mismatch Slope Testing

Three-phase testing is to be performed by applying a balanced 3-phase current into one input configured for HV and a second input configured for LV. The 87 High Mismatch slope characteristic is typically proven on a simulated through fault where the current is into the transformer on the source side and out of the transformer on the faulted side.

For the example of Figure 7.31: on page 7-43, the HV shift is 0°. Let the HV be the reference where current into HV = 0°.

We inject 3 Phase HV current at angles:

Ph A ∠0º

Ph B ∠-120º

Ph C ∠120º

The LV shift of Figure 7.31: on page 7-43 is -30° from the HV side. For through fault simulation, we shift the LV current by an additional 180°.

Ph A ∠(0°-30°+180°) = Ph A ∠+150°

Ph B ∠(-120°-30°+180°) = Ph B ∠+30°

Ph C ∠(120°-30°+180°) = Ph C ∠+270°

The calculations to perform the 87 High Mismatch points in Figure 7.33: on page 7-46 shall be demonstrated.

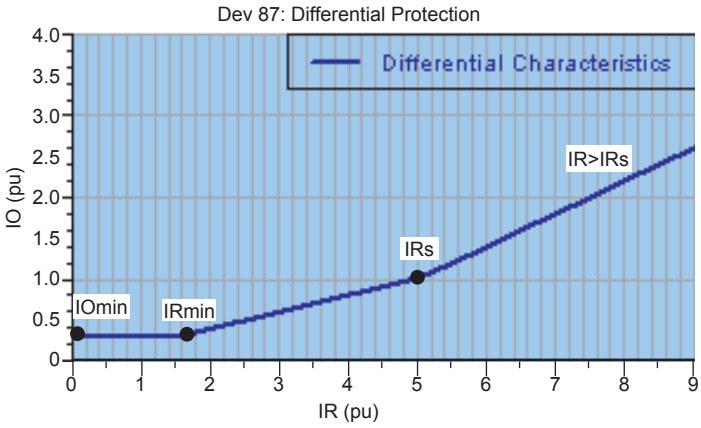


Figure 7.33: High Mismatch Test Points

First Test Point: IO_{min}

= 0.3 per unit, IR = 0.15 per unit

The following equations 2 and 3 are used to determine the operating currents for the 87 Mismatch slope characteristic:

$$IO = \overrightarrow{I_{HV}} + \overrightarrow{I_{LV}} \quad (28)$$

or for an ideal through fault

$$IO = |I_{HV}| - |I_{LV}| \quad (29)$$

$$IR = \frac{|I_{HV}| + |I_{LV}|}{2} \quad (30)$$

For the HV IO_{min} test no LVcurrent is injected, so $I_{LV} = 0$:

The IO_{min} setting = 0.3 per unit

Using Equation (28) on page 7-46:

0.3 pu = I_{HV} - I_{LV}

0.3 pu = I_{HV} - 0

I_{HV} = 0.3 pu.

$I_{HV\ Sec\ Amps}$ = 0.3 pu x $I_{HV\ Base\ Sec}$ = 0.3 x 1.004 A = 0.301 A

For LV IO_{min} test, no HV current is injected so $I_{HV} = 0$:

IO_{min} setting = 0.3 per unit

Using Equation (28) on page 7-46:

0.3 pu = I_{LV} - I_{HV}

$0.3 \text{ pu} = I_{LV} - 0$

$I_{LV} = 0.3 \text{ pu}$

$I_{LV \text{ Sec Amps}} = 0.3 \text{ pu} \times I_{LV \text{ Base Sec}} = 0.3 \times 1.004 \text{ A} = 0.301 \text{ A}$

Figure 7.34: on page 7-47 shows the summary of the IO_{min} calculation for each side of the transformer.

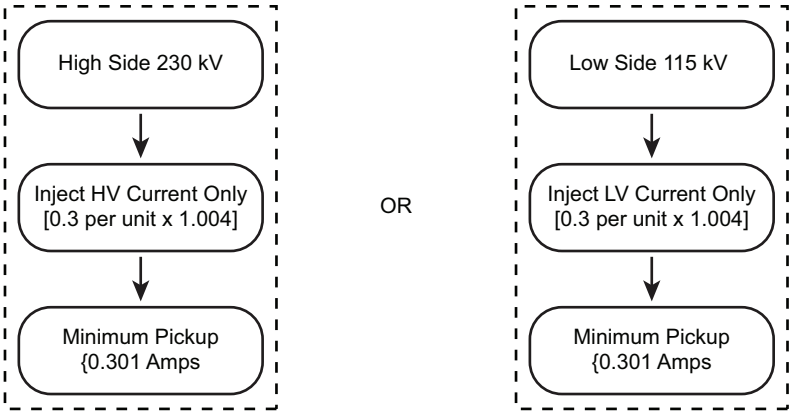


Figure 7.34: Summary of Minimum Operating Current of the Differential Element

IO_{min} Test Procedure:

1. Access Relay Control Panel *Metering > Logic 2* or Front HMI, *Metering > Logic > Logic Protections 2*.

   Monitor for pickup:

   87 High Mismatch

   87 Trip

2. HV IO_{min} Test

   Connect balanced 3-phase current to terminals: A 300 ─ 301, B 302 ─ 303, C 304 ─ 305

   Slowly ramp the current up from zero until 87 High Mismatch changes from Low to High.

   At 0.29 to 0.31 A (Expect 0.301 A):

   87 High Mismatch = High

   87 Trip = High

3. LV IO_{min} Test

   Connect balanced 3-phase currents to terminals: A 306 ─ 307, B 308 ─ 309, C 310 ─ 311

   Slowly ramp the currents up from zero until 87 High Mismatch changes from Low to High.

   At 0.29 to 0.31 A (Expect 0.301 A)

   87 High Mismatch = High

   87 Trip = High

4. End of 87 IO_{min} Test

Second Test Point IR_{min}

IO = 0.3 per unit, IR = 1.50 per unit

IR_{min} (from Figure 7.33: on page 7-46) is determined from the IO_{min} and Slope 1 settings in (31) on page 7-48.

IO_{min} setting = 0.3 pu, Slope 1 setting = 20%.

$$IR_{min} = \frac{100 \times IO_{min}}{S1} \quad (31)$$

IR_{min} = (100 * 0.3) / 20 = 1.5 pu.

We will then use the mathematical elimination and substitution methods on Equations 2 and 3 to determine the I_{HV} and I_{LV} test currents.

Solve for I_{HV} and I_{LV} at IO = 0.3 per unit and IR_{min} = 1.5 per unit.

Use above Formulas (29) on page 7-46 and (30) on page 7-46 to solve for IO and IR.

$$IO = I_{HV} - I_{LV}$$

$$0.3 = I_{HV} - I_{LV} \quad \text{(Part 1)}$$

$$IR = \frac{\langle I_{HV} + I_{LV} \rangle}{2}$$

$$1.5 = \frac{\langle I_{HV} + I_{LV} \rangle}{2}$$

$$1.5 \times 2 = I_{HV} + I_{LV}$$

$$3.0 = I_{HV} + I_{LV} \quad \text{(Part 2)}$$

Solve for ILV by Subtracting the equation Part2 from Part1:

0.3 pu = I_{HV} - I_{LV} (Part 1)

\- 3.0 pu = I_{HV} + I_{LV} (Part 2)

Total -2.7pu = 0 - 2I_{LV}

$$\frac{-2.7 \text{ pu}}{-2} = I_{LV} = 1.35 \text{ pu}$$

$I_{LVAmps} = I_{LVBaseSec} \times I_{LVpu} = 1.004\ A \times 1.35\ pu = 1.36$

Substitute the I_{LV} per unit value back into Part1 to solve for I_{HV}.

$IO = I_{HV} - I_{LV}$

$1.0\ pu = I_{HV} - 1.35\ pu$

$I_{HV} = 1.65\ pu$

$I_{HVAmps} = I_{HVBaseSec} \times I_{HVpu} = 1.004\ A \times 1.65\ pu = 1.66\ A$

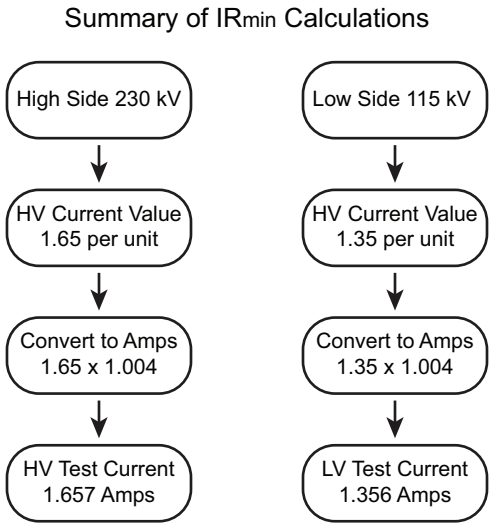


Figure 7.35: Summary of IR_{min} Calculations

IR_{min} Test Procedure:

1. Access Relay Control Panel *Metering* > *Logic 2* or Front HMI, *Metering* > *Logic* > *Logic Protections 2*.

   Monitor for pickup:

   87 High Mismatch

2. Connect 1st set of balanced 3-phase currents to LV terminals:

   Ph A: Terminals 306 ─ 307: 1.36A∠150

   Ph B: Terminals 308 ─ 309: 1.36A∠+30

   Ph C: Terminals 310 ─ 311: 1.36A∠-90°

   Connect 2nd set of balanced 3-phase current to HV terminals @ 90% of I_{HV} pickup:

   Ph A: Terminals 300 ─ 301: 90% x 1.66A = 1.49A∠0°

   Ph B: Terminals 302 ─ 303: 90% x 1.66A = 1.49A∠+30°

   Ph C: Terminals 304 ─ 305: 90% x 1.66A = 1.49A∠-90°

   Observe 87 High Mismatch = Low.

3. Slowly and simultaneously ramp up the 3 phase magnitudes of the HV currents

   At 1.60 to 1.75 A (expect 1.66 A)

   87 High Mismatch = High

4. End of IRmin Test

Third Test Point, IRs

IO = 1.0 pu, IR = 5.0 pu

The third point shown in Figure 7.33: on page 7-46 is IRs. IO at IRs is determined from the IRs, Slope1 and Slope2 settings in (32) on page 7-50.

$$IO = \frac{S2 \times IR}{100} + \frac{S1\text{-}S2}{100} \times IRs \qquad (32)$$

IRs setting = 5.0pu, Slope1 setting = 20%, Slope2 setting = 40%.

$$IO = \frac{40 \times 50}{100} + \frac{20\text{-}40}{100} \times 5.0 = 2 + (-0.2 \times 5.0) = 1.0pu$$

We will then use the mathematical elimination and substitution methods on Equations (28) and (30) on page 7-46 to determine the I_{HV} and I_{LV} test currents.

Solve for I_{HV} and I_{LV} at IO = 1.0 and IR = IRs = 5.0 per unit.

Use above equations (28) and (30) on page 7-46 to solve for IO and IR.

$$IO = I_{HV} - I_{LV} \qquad (33)$$

$$1.0 = I_{HV} - I_{LV} \qquad \text{(Part 1)}$$

$$IR = \frac{\langle I_{HV} + I_{LV} \rangle}{2} \qquad (34)$$

$$5.0 = \frac{(I_{HV} + I_{LV})}{2}$$

$$5.0 \times 2 = I_{HV} + I_{LV}$$

$$10.0 = I_{HV} + I_{LV} \qquad \text{(Part 2)}$$

Solve for I_{LV} by eliminating IHV by subtracting the equation Part 2 from Part 1:

$$1.0 \text{ pu} = I_{HV} - I_{LV} \text{ (Part 1)}$$

$$- \quad 10.0 \text{ pu} = I_{HV} + I_{LV} \text{ (Part 2)}$$

$$\text{Total} \quad -9.0 \text{ pu} = 0 - 2I_{LV}$$

$$\frac{-9.0 \text{ pu}}{-2} = I_{LV} = 4.50 \text{ pu}$$

$I_{LVAmps} = I_{LVBaseSec} \times I_{LVpu} = 1.004 \text{ A} \times 4.50 \text{ pu} = 4.52 \text{ A}$

Substitute the I_{LV} per unit value back into Part 1 to solve for I_{HV}.

$IO = I_{HV} - I_{LV}$

$1.0 \text{ pu} = I_{HV} - 4.50 \text{ pu}$

$I_{HV} = 5.50 \text{ pu}$

$I_{HVAmps} = I_{HVBaseSec} \times I_{HVpu} = 1.004 \text{ A} \times 5.50 \text{ pu} = 5.52 \text{ A}$

Summary of IRs Calculations:

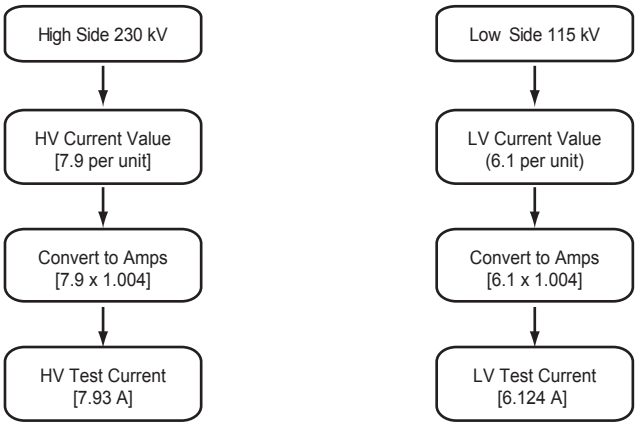


Figure 7.36: Summary of IRs Calculations:

IRs Test Procedure:

1. Access Relay Control Panel *Metering* > *Logic 2* or Front HMI, *Metering* > *Logic* > *Logic Protections 2*.
2. Monitor for pickup:

   87 High Mismatch
3. Connect 1st set of balanced 3-phase currents to LV terminals:

   Ph A: Terminals 306 – 307: 4.52A∠150°

   Ph B: Terminals 308 – 309: 4.52A∠+30°

   Ph C: Terminals 310 – 311: 4.52A∠-90°

   Connect 2nd set of balanced 3-phase currents to HV terminals @ 90% of I_{HV} pickup:

   Ph A: Terminals 300 – 301: 90% x 5.52A = 4.97A∠0°

   Ph B: Terminals 302 – 303: 90% x 5.52A = 4.97A∠+30°

   Ph C: Terminals 304 – 305: 90% x 5.52A = 4.97A∠-90°

   Observe 87 High Mismatch = Low.
4. Slowly and simultaneously ramp up the 3 phase magnitudes of the HV currents.

   At 5.40 to 5.65 A (expect 5.52 A)

   87 High Mismatch = High
5. End of IRs Test

Fourth Test Point, IR > IRs

IO = 1.8 pu, IR = 7.0 pu

The fourth test point shown in Figure 7.31: on page 7-43 is an arbitrary point in Slope 2. We chose IR = 7.0 per unit.

We find IO at IR = 7.0 from the IRs, Slope 1 and Slope 2 settings in Equation (32) on page 7-50.

$$IO = \frac{S2 \times IR}{100} + \frac{S1 - S2}{100} \times IRs \qquad (35)$$

IRs setting = 5.0 pu, Slope 1 setting = 20%, Slope 2 setting = 40%.

$$IO = \frac{40 \times 7.0}{100} + \frac{20 - 40}{100} \times 5.0 = (2.8 + (-0.2 \times 5)) = 1.8pu$$

We then use the mathematical elimination and substitution methods on Equations (28) and (30) on page 7-46 to determine the I_{HV} and I_{LV} test currents.

Solve for I_{HV} and I_{LV} at IO = 1.8 and IR = 7.0 per unit.

Use above Formulas (28) and (30) on page 7-46 to solve for IO and IR.

$$IO = I_{HV} - I_{LV}$$

$$1.8 = I_{HV} - I_{LV} \qquad \text{(Part 1)}$$

$$IR = \frac{I_{HV} + I_{LV}}{2}$$

$$7.0 = \frac{(I_{HV} + I_{LV})}{2}$$

$$7.0 \times 2 = I_{HV} + I_{LV}$$

$$14.0 = I_{HV} + I_{LV} \qquad \text{(Part 2)}$$

Solve for I_{LV} by eliminating I_{HV} by subtracting the equation Part 2 from Part 1: Substitute the I_{LV} per unit value back into Part 1 to solve for I_{HV}.

$$1.8pu = I_{HV} - I_{LV} \qquad \text{(Part 1)}$$

$$- \quad 14.0pu = I_{HV} + I_{LV} \qquad \text{(Part 2)}$$

Total $-12.2pu = 0 - 2I_{LV}$

$$\frac{-12.2pu}{-2} = I_{LV} = 6.10pu$$

$I_{LVAmps} = I_{LVBaseSec}$ x I_{LVpu} = 1.004 A x 4.50 pu = 6.12 A

Substitute the I_{LV} per unit value back into Part1 to solve for I_{HV}.

$$IO = I_{HV} - I_{LV}$$

$$1.8pu = I_{HV} - 6.10pu$$

$$I_{HV} = 7.90pu$$

$I_{HVAmps} = I_{HVBaseSec}$ x I_{HVpu} = 1.004 A x 7.90 pu = 7.93 A

Summary of IR>IRs Calculations:

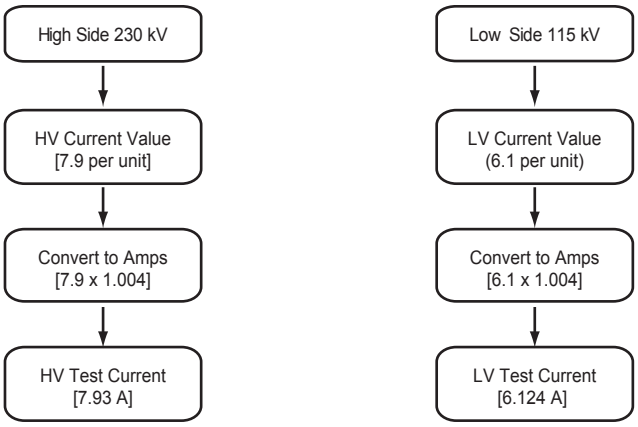


Figure 7.37: Summary of IR>IRs Calculations

IR > IRs Test Procedure:

1. Access Relay Control Panel *Metering* > *Logic 2* or Front HMI, *Metering* > *Logic* > *Logic Protections 2*.

   Monitor for pickup:

   - 87 High Mismatch

2. Connect 1st set of balanced 3-phase currents to LV terminals:

   Ph A: Terminals 306 – 307: 6.12A∠150°

   Ph B: Terminals 308 – 309: 6.12A∠+30°

   Ph C: Terminals 310 – 311: 6.12A∠-90°

   Connect 2nd set of balanced 3-phase currents to HV terminals @ 90% of I_{HV} pickup:

   Ph A: Terminals 300 – 301: 90% x 7.93A = 7.14A∠0°

   Ph B: Terminals 302 – 303: 90% x 7.93A = 7.14A∠+30°

   Ph C: Terminals 304 – 305: 90% x 7.93A = 7.14A∠-90°

   Observe 87 High Mismatch = Low.

3. Slowly and simultaneously ramp up the 3 Phase magnitudes of the HV currents:

   At 7.80 to 8.15A (expect 7.93A)

   87 High Mismatch = High

4. End of IR>IRs Test

   87 High Mismatch = High

   4. End of IR>IRs Test

Summary of Three-Phase Test

1. Calculate base current for each side.
2. Determine IO (operating) and IR (restraint) values to be tested.
3. Calculate I_{HV} and I_{LV} per unit currents for a given IO and IR.
4. Adjust angles by Current Phase Correction ("Current Phase Correction Table" in Appendix L) and convert I_{HV} and I_{LV} per units to amperes.
5. Apply I_{HV} and I_{LV} with 3-phase sources. Set reference side at zero degrees (0.0°) for current into the transformer, and the opposite side at the opposing angle for current out of the transformer. In this example, -30+180° = 150° to account for the -30° delta shift.

7.6 T- PRO Single-Phase Slope Test

Performing Single Phase testing of the T-PRO slope requires many calculations. In order to complete the process satisfactorily, one needs to get a very good understanding of the CPC tables of "Current Phase Correction Table" in Appendix L and how they are used by the relay to normalize the angles and eliminate zero sequence current.

To explain the Single Phase Slope test, we start with a summary of the steps, then provide details of each step, and follow up with an example using our example transformer of for details see Figure 7.31: T-PRO Differential Slope Test Example on page 7-43.

Steps to perform Single-Phase Testing

1. Perform the current calculations for 3-phase testing from the previous section.
2. Determine the net current angle on each current input associated with each transformer winding. In order to organize the shift of each input, it's helpful to create a Net Angle Table (NAT) such as Table 7.1: on page 7-56.

Table 7.1: Example of a Net Angle Table

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
T-PRO Input	Associated Winding	Winding Angle	CT Angle	Total Angle (Column 3 + Column 4)	Use Current Phase Correction Equations of Appendix L (Correction = -1 x Column 5)
Input 1					
Input 2					
Input 3					
Input 4					
Input 5					

3. Determine which phase (s) to inject on each side.
4. Apply the additional magnitude correction factor of 1.0 or √3 to the calculated 3-phase test currents.

Detailed Steps for Single Phase Testing

To help in understanding the relationship between what the T-PRO actually sees when you inject a single phase current, it helps to view the Relay Control Panel *Metering>Analog* as shown in Figure 7.38: on page 7-57. The metering screen also provides a place to quickly verify that your calculations are correct.

In Figure 7.38: on page 7-57, currents IA1, IB1…etc. are uncompensated currents (they follow your injected currents). The currents HV IA, HV IB…etc. are the compensated currents after phase corrections and zero sequence elimi-

nation (i.e., after corrections of "Current Phase Correction Table" in Appendix L).

On Figure 7.39: HV, LV, TV Compensated Operating Currents on page 7-58 Analog has the per unit operating and restraint currents.

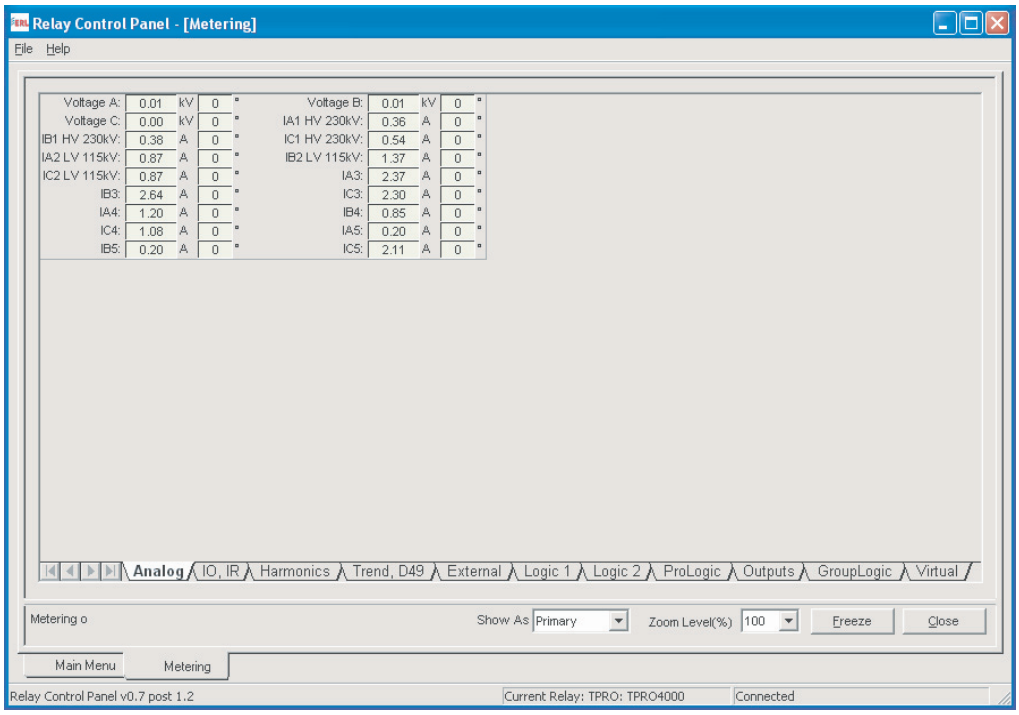

Relay Control Panel - [Metering]
File Help
Voltage A: 0.01 kV 0 °
Voltage B: 0.01 kV 0 °
Voltage C: 0.00 kV 0 °
IA1 HV 230kV: 0.36 A 0 °
IB1 HV 230kV: 0.38 A 0 °
IC1 HV 230kV: 0.54 A 0 °
IA2 LV 115kV: 0.87 A 0 °
IB2 LV 115kV: 1.37 A 0 °
IC2 LV 115kV: 0.87 A 0 °
IA3: 2.37 A 0 °
IB3: 2.64 A 0 °
IC3: 2.30 A 0 °
IA4: 1.20 A 0 °
IB4: 0.85 A 0 °
IC4: 1.08 A 0 °
IA5: 0.20 A 0 °
IB5: 0.20 A 0 °
IC5: 2.11 A 0 °
Analog IO, IR Harmonics Trend, D49 External Logic 1 Logic 2 ProLogic Outputs GroupLogic Virtual
Metering o
Show As Primary
Zoom Level(%) 100
Freeze
Close
Main Menu
Metering
Relay Control Panel v0.7 post 1.2
Current Relay: TPRO: TPRO4000
Connected

Figure 7.38: Analog Input Metering

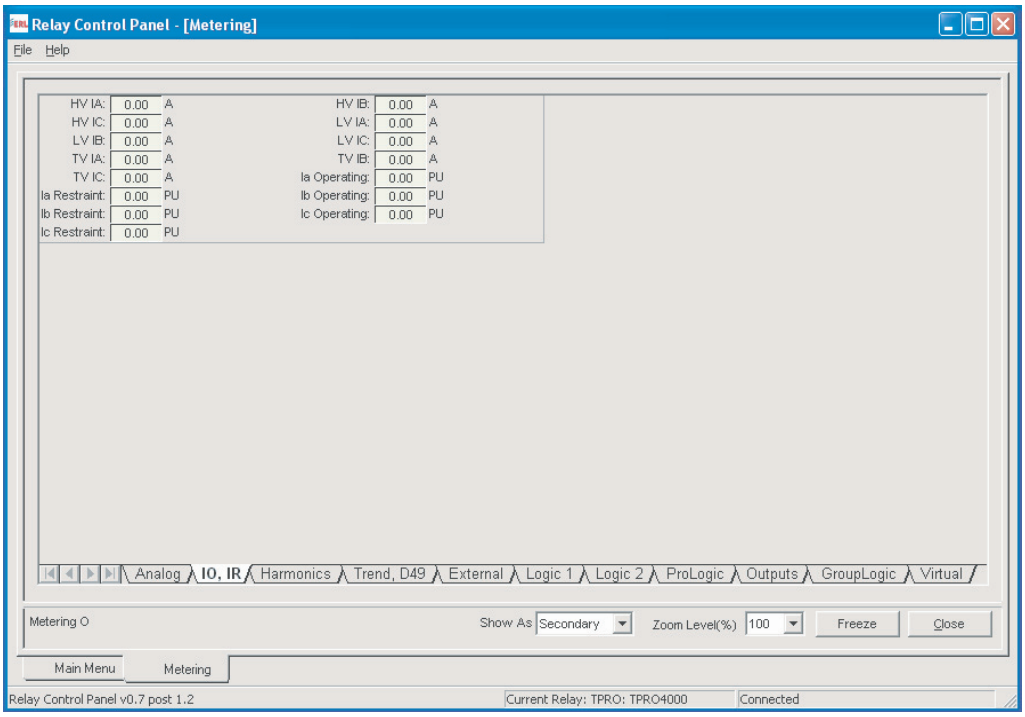


Figure 7.39: HV, LV, TV Compensated Operating Currents

Step 1:

Perform the 3-phase calculations for each slope point to be tested.

You must perform the 3-phase slope calculations prior to attempting the following Single-phase slope test procedure. This is because single phase test quantities for any point on the slope are adapted from your 3-phase test quantities.

See the 3-Phase High Mismatch Slope test section for the procedure to obtain the 3-phase test currents for any point on the slope characteristic.

Step 2:

Determine net phase shift of each T-PRO current input. To simplify the process, create a Net Angle Table such as Table 7.1: on page 7-56.

Sum the suffixes of your Winding and CT configurations and enter them into your Net Angle Table (NAT).

Examples of angles to enter into your table:

Delta +30° → enter “+30°”

Delta +60° → enter “+60°”

Wye -30° → Enter “-30°”

Delta 0° → Enter “0°”

Wye 180° → Enter “180°”

Etc…

This is a Net Angle Table (NAT) that we created for our example transformer of Figure 7.22. Transformer is connected Wye 0°, Delta -30, and with Wye 0° CTs on both sides.					
Column 1	**Column 2**	**Column 3**	**Column 4**	**Column 5**	**Column 6**
T-PRO Input	Associated Winding	Winding Angle	CT Angle	Total Angle (Column 3 + Column 4)	Use CPC Equations of Appendix L (Correction = -1 x Column 5)
Input 1	HV	Wye 0°	Wye 0°	0°	0° (CPC12)
Input 2	LV	Delta -30°	Wye 0°	-30°	+30° (CPC1)
Input 3	NA	-	-	-	-
Input 4	NA	-	-	-	-
Input 5	NA	-	-	-	-

Step 3:

The ultimate goal of Step 3 is to always obtain 2 operating phases from a single current source on each transformer side. We will demonstrate how to select which phase or phases to inject so that two operating phases are always obtained.

We use ideal external faults for proving the 87 High Mismatch slope characteristic. In order to perform a proper differential slope test, any Operating phases are seen in one side of the transformer must be mirrored on the other side. For example if you have operating current in phases A & B of the HV side, you must also have operating current in phases A & B on the LV side in order to simulate an external (through) fault.

Also, for simulating an ideal external fault, the phases on one side must be 180° out of phase from the other side. For example, where an external fault has A-B on HV side, there must be – (A-B) or B-A on the LV side.

Use the Single-Phase Selection Tables (Table 7.2: on page 7-61, Table 7.3: on page 7-61 and Table 7.4: on page 7-62) to determine which phase (s) to inject for your single phase 87 High Mismatch test:

The Single Phase Selection Tables (SPST; i.e., Table 7.2: on page 7-61, Table 7.3: on page 7-61 and Table 7.4: on page 7-62) may be used to quickly determine which phase or phases will have Operating current if you inject only Phase A (Table 7.2: on page 7-61, Table 7.3: on page 7-61 and Table 7.4: on page 7-62). The Operating phase (s) for an input shall depend on which winding it is associated, and that inputs net angle. You can determine the net angle and document your calculations in the NAT created in Step 2.

Each SPST (Tables Table 7.2: on page 7-61, Table 7.3: on page 7-61 and Table 7.4: on page 7-62) have 3 columns labeled *Left*, *Middle* and *Right*.

- The Left column of each SPST shows the net angle for a particular transformer winding associated with a particular T-PRO input. (Note that SPST Left column also corresponds to Column 5 of our NAT.)
- The Middle column of SPST corresponds to the angle nulling equations of the Current Phase Correction Table in Appendix L. (Note that SPST Middle column also corresponds to Column 6 of our NAT.)
- The Right column of SPST shows which phase (s) of the T-PRO will have Operating current if you inject Only the specified input phase A, or B, or C. By "Operating" current, we are referring to the phase or phases inside the T-PRO 87 element that have the greatest current magnitude once all internal corrections have been applied; thus the phases that would exceed IOmin and trip first.
- To give an example of how the phases in Right column are obtained, here is an example using the Wye 0 connection. From SPST Table 7.2, inject Only Ia at 0. Since the connection is 0, use CPC12 formulas in Appendix L:

$$IA = \frac{2Ia - Ib - Ic}{3} = \frac{2(1amp) - (0amp) - (0amp)}{3} = \frac{2amp}{3} = 0.67amp \quad (36)$$

$= 0.67\text{amp}\angle 0°$

$$IB = \frac{-Ia + 1Ib - Ic}{3} = \frac{-(1amp) + 2(0amp) - (0amp)}{3} = \frac{-1amp}{3} = -0.33amp \quad (37)$$

$= -0.33\text{amp}\angle 180°$

$$IC = \frac{-Ia - Ib + 2Ic}{3} = \frac{-(1amp) - (0amp) + 2(0amp)}{3} = \frac{-1amp}{3} = 0.33amp \quad (38)$$

$= 0.33\angle 180°$

IA at 0.67 A is the strongest phase, twice as strong as IB and IC which are 0.33 A. Therefore we would expect that the T-PRO Phase A differential will operate first. Note that IA is also in-phase with the injected current.

We have just proven the Table 7.2: on page 7-61, 0 connection. Where the left column is 0, the right column will have the strongest current in Phase A at $\angle 0°$.

Each SPST row uses the same process; the Operating phases are determined from the appropriate CPC equations of "Current Phase Correction Table" in Appendix L.

At the beginning of Step 3 we stated that we must see 2 operating phases on each side. Since we found in this example that injecting IA will only result in one Operating phase ($A\angle 0°$), we will have to inject a second phase to obtain two operating phases. We will show how to do that in our example transformer later in this section.

Table 7.2: Single-Phase Selection Table (Inject Phase A only at 0°)			
	Left	**Middle**	**Right**
	Select the Winding Net Phase Angle (degrees)	**Use Formulas from Current Phase Correction Table (Appendix L)**	**Injecting only T-PRO Phase A at 0° shows these "Operating" Phases)**
i	–30º	+30º (CPC1)	A∠0 & C∠180
ii	–60º	+60º (CPC2)	C180
iii	–90º	+90º (CPC3)	B∠0 & C∠180
iv	–120º	+120º (CPC4)	B∠0
v	–150º	+150º (CPC5)	B∠0 & A∠180
vi	–180º	+180º (CPC6)	A∠180
vii	–210º	+210º (CPC7)	C∠0 & A∠180
viii	–240º	+240º (CPC8)	C∠0
ix	–270º	+270º (CPC9)	C∠0 & B∠180
x	–300º	+300º (CPC10)	B∠180
xi	–330º	+330º (CPC11)	A∠0 & B∠180
xii	0º	360º (CPC12)	A∠0

Table 7.3: Single-Phase Selection Table (Inject Phase B only at 0°)			
	Left	**Middle**	**Right**
	Select the Winding Net Phase Angle (degrees)	**Use Formulas from CPC (Appendix L)**	**Injecting only T-PRO Phase B at 0° shows these "Operating" Phase (s)**
i	–30º	+30º (CPC1)	B∠0 & A∠180
ii	–60º	+60º (CPC2)	A180
iii	–90º	+90º (CPC3)	C∠0 & A∠180
iv	–120º	+120º (CPC4)	C∠0
v	–150º	+150º (CPC5)	C∠0 & B∠180
vi	–180º	+180º (CPC6)	B∠180
vii	–210º	+210º (CPC7)	A∠0 & B∠180
viii	–240º	+240º (CPC8)	A∠0
ix	–270º	+270º (CPC9)	A∠0 & C∠180

Table 7.3: Single-Phase Selection Table (Inject Phase B only at 0°)			
	Left	**Middle**	**Right**
	Select the Winding Net Phase Angle (degrees)	**Use Formulas from CPC (Appendix L)**	**Injecting only T-PRO Phase B at 0° shows these "Operating" Phase (s)**
x	–300º	+300º (CPC10)	C∠180
xi	–330º	+330º (CPC11)	B∠0 & C∠180
xii	0º	+360º (CPC12)	B∠0

Table 7.4: Single-Phase Selection Table (Inject Phase C only at 0°)			
	Left	**Middlle**	**Right**
	Select the Winding Net Phase Angle (degrees)	**Use Formulas from Current Phase Correction Table (Appendix L)**	**Injecting only T-PRO Phase C at 0° shows these "Operating" Phase(s)**
i	–30º	+30º (CPC1)	C∠0 & B∠180
ii	–60º	+60º (CPC2)	B∠180
iii	–90º	+90º (CPC3)	A∠0 & B∠180
iv	–120º	+120º (CPC4)	A∠0
v	–150º	+150º (CPC5)	A∠0 & C∠180
vi	–180º	+180º (CPC6)	C∠180
vii	–210º	+210º (CPC7)	B∠0 & C∠180
viii	–240º	+240º (CPC8)	B∠0
ix	–270º	+270º (CPC9)	B∠0 & A∠180
x	–300º	+300º (CPC10)	A∠180
xi	–330º	+330º (CPC11)	C∠0 & A∠180
xii	0º	+360º (CPC12)	C∠0

Step 4

Determine the additional Magnitude Correction Factor:

Using the 2 operating phase method, you only need to remember two single phase Magnitude Correction Factors, 1.0 and √3. The values in the Table 7.5: on page 7-63 can be proven by manually calculating the phase shift resultants using the "Current Phase Correction Table" in Appendix L.

Multiply the 3-phase current values determined in your 3 phase test calculations by the correction factor in the right column of the Table 7.5: on page 7-63.

Table 7.5 relates the Net Transformer Shift angle to the applicable Magnitude Correction Factor:

Table 7.5: Single-Phase Correction Factor Table

Transformer Net Phase Shift (degrees)	Additional Magnitude Correction Factor (Multiplier)
–30º	√3
–60º	1.0
–90º	√3
–120º	1.0
–150º	√3
–180º	1.0
–210º	√3
–240º	1.0
–270º	√3
–300º	1.0
–330º	√3
0º	1.0

Example of the Single-Phase Testing Calculation Steps

Step 1:

See the example transformer in Figure 7.33: High Mismatch Test Points on page 7-46, these are the T-PRO settings:

- MVA: 100
- Windings: 2
- HV kV: 230 (Y 0°)
- LV kV: 115 (Delta -30°)

- HV CT: 250:1 (Y 0°)
- LV CT: 500:1 (Y 0°)
- PT Location: High Side
- IO_{min}: 0.3 per unit
- IRs: 5.0 per unit
- Slope 1: 20%
- Slope 2: 40%

For this example, we will choose the IR_{min} 3 phase test currents.

In the "First Test Point: IOmin" on page 7-46 (Equation (28) and (30)) we calculated IR = 1.50 per unit.

In the "Second Test Point IRmin" on page 7-48 we calculated the LV 3 phase test currents = 1.35 A and the HV 3 phase test currents = 1.66 A.

Step 2

Determine the net phase shift for each input.

In our example, only Input 1 and Input 2 are used. We create our Net Angle Table accordingly:

Table 7.6: Net Angle Table

Column 1	Column 2	Column 3	Column 4	Column 5	Column 6
T-PRO Input	**Associated Winding**	**Winding Angle**	**CT Angle**	**Total Angle (Column 3 + Column 4)**	**Use CPC Equations Appendix L (Correction = -1 x Column 5)**
Input 1	HV	Wye 0°	Wye 0°	0°	0° (CPC12)
Input 2	LV	Delta -30°	Wye 0°	-30°	+30° (CPC1)
Input 3	NA	-	-	-	-
Input 4	NA	-	-	-	-
Input 5	NA	-	-	-	-

Step 3

Always obtain the same 2 operating phases on both sides of the transformer:

We demonstrate the use of our Net Angle Table (NAT) and Single Phase Selection Tables (SPST) to determine which phase or phases to inject to have complementary phases on either side of the transformer.

- Our example transformer is HV Y0° (Input1) and LV Delta-30° (Input2). T-PRO always nulls the angle on all inputs, even if they are already 0°, since it also needs to eliminate zero sequence.
- Lookup Input1 in our NAT and find the net angle in Column 5; we find that it is 0°.
- Lookup Input 2 in our NAT and find the net angle in Column 5; we find that it is -30°.
- First we will obtain two operating phases on Input1, and then we'll obtain the exact same phases on Input2. We can arbitrarily choose to obtain any two Operating phases; we will choose A-B (i.e., A∠0° & B∠180°).

Determine Input 1 Injection:

Input 1 net angle is 0° (same as 360°) so we will start systematically by looking first in left column of SPST Table 7.2 (Operating current if you inject only phase A). We find the 0° connection in row "xii". The right column states that if we inject Phase A at 0° we get Operating Phase A∠0°. This is good because phase A is one of the Operating phases we have chosen to obtain (to get A-B).

The proof of our SPST 7.2 result is found (as stated in the header of in the middle column), by using CPC12 formulas in Appendix L. For simplicity, we use 1.0A in the CPC12 formulas to find the Operating phase (s) if we inject only Phase A. We get the following results (Confirm in Metering>Analog):

$$IA = \frac{2Ia - Ib - Ic}{3} = \frac{2(1amp) - (0amp) - (0amp)}{3} = \frac{2amp}{3} = 0.67amp \quad (36)$$

= 0.67amp∠0°

$$IB = \frac{-Ia + 2Ib - Ic}{3} = \frac{-(1amp) + 2(0amp) - (0amp)}{3} = \frac{-1amp}{3} = 0.33amp \quad (37)$$

= -0.33amp∠180°

$$IC = \frac{-Ia - Ib + 2Ic}{3} = \frac{-(1amp) - (0amp) + 2(0amp)}{3} = \frac{-1amp}{3} = 0.33amp \quad (38)$$

= 0.33∠180°

The strongest phase is the Operating phase. and IA is the strongest phase at 0.67amp∠0°; we can ignore IB and IC as they are not the strongest phases.

Since our stated goal is to have Operating phases A-B, we will need to inject a 2nd phase. We have just established how to get Operating phase A so now we will need to add Operating phase –B (i.e., Phase B at 180°).

We have already used SPST 7.2 for this input, so now we need to look at SPST 7.3 and SPST 7.4 and see which one will give Operating Phase B in row "xii" for our 0 connection.

We find in the right column of SPST 7.3 row "xii" that if we inject Phase B, we get Operating Phase B, which is what we were seeking. For proof of the right column, we again insert 1.0 A into Phase B of CPC12 formulas and see that in this case IB is 0.67 A, while IA and IC are only 0.33 A. (Confirm in Metering>Analog.

$$IA = \frac{2Ia - Ib - Ic}{3} = \frac{2(0amp) - (1amp) - (0amp)}{3} = \frac{-1amp}{3} = 0.33amp$$

$= 0.33\text{amp}\angle 0°$

$$IB = \frac{-Ia + 2Ib - Ic}{3} = \frac{-(0amp) + 2(1amp) - (0amp)}{3} = \frac{2amp}{3} = -0.67(0.33)amp$$

$= -0.67\text{amp}\angle 180°$

$$IC = \frac{-Ia - Ib + 2Ic}{3} = \frac{-(0amp) - (1amp) + 2(0amp)}{3} = \frac{-1amp}{3} = 0.33amp$$

$= 0.33\angle 180°$

We now have proof that for a 0° connection, if we inject Phase B only at 1 amp ∠0°, we will get operating current in phase B phase only. Since we know that we need B to be at 180° (for A-B), we simply reverse the test set current to inject into the non-polarity of B Phase input.

We have established how to get individual Operating phases A and –B on our HV Input 1. However, we need to get two Operating phases (A-B) at once from a single source, so we will put our findings together into CPC12 again and ensure that we get only HV A – B Operating currents.

Simultaneously insert 1.0 A into Ia and -1.0 A into Ib:

$$IA = \frac{2Ia - Ib - Ic}{3} = \frac{2(1amp) - (0amp) - (0amp)}{3} = \frac{2amp}{3} = 0.67amp \quad (36)$$

$= 0.67\text{amp}\angle 0°$

$$IB = \frac{-Ia + 2Ib - Ic}{3} = \frac{-(1amp) + 2(0amp) - (0amp)}{3} = \frac{-1amp}{3} = 0.33amp \quad (37)$$

$= -0.33\text{amp}\angle 180°$

$$IC = \frac{-Ia - Ib + 2Ic}{3} = \frac{-(1amp) - (0amp) + 2(0amp)}{3} = \frac{-1amp}{3} = 0.33amp \quad (38)$$

$= 0.33\angle 180°$

HV Operating phases are A-B. We can now determine our test connections for Input 2.

Determine Input 2 Injection:

Find required inject to obtain A-B on the LV (-30°) side.

In NAT Column 5 we find LV (Input2) net shift is -30°. Lookup -30° in the left column of SPST which we find in row "i". We are seeking which one or two SPS Tables we will need to utilize to get only Operating phases A and B in row "i".

We find that Phases A and B appear in row "i" of SPST 7.3. If we inject only Phase B, we will get operating phases A and B. However, it is actually B-A (i.e., B∠0° & A∠180°). This is acceptable. As long as we have the correct phases we can easily compensate for any angle difference by simply changing our test set connections at the relay to achieve the required 0° or 18°0. If inject +B gives us B-A, we should be able to get A-B by injecting –B. i.e., –(B-A) = A-B

To confirm the phases shown in SPST 7.3 are correct, we use the "Current Phase Correction Table" in Appendix L. The LV connection is -30° and the correction angle is: (-1 ´ -30°) = +30°, therefore CPC1 is applicable for our LV connection. We insert 1.0 A where "Ib" appears in the CPC1 formulas. This will confirm that we get only Operating phases IB and IA when we inject only Phase B.

Confirm in Metering>Analog.

$$IA = \frac{Ia - Ib}{\sqrt{3}} = \frac{0amp - 1amp}{\sqrt{3}} = \frac{-1}{\sqrt{3}} = -0.577amp \quad (39)$$

= -0.577amp∠180°

$$IB = \frac{Ib - Ic}{\sqrt{3}} = \frac{1amp - 0amp}{\sqrt{3}} = \frac{1}{\sqrt{3}}0.577amp \quad (40)$$

= 0.577amp∠0°

$$IC = \frac{Ic - Ia}{\sqrt{3}} = \frac{0amp - 0amp}{\sqrt{3}} = \frac{0}{\sqrt{3}} = 0amp \quad (41)$$

= 0amp

Summarize All of Our Injection Determinations:

We have concluded that in order to do our Single Phase differential test, we should inject into A-B on the HV side to get A-B into Input 1, and inject -B on the LV side to get A-B into Input 2).

Note that both of these connections give A-B current into the transformer. Since slope testing simulates an external fault (one side into and one side out of), one side needs to be 180° out of phase from the other side. The connections and test current source angles shown in Figure 7.40: on page 7-68 will result in currents on LV being 180° out of phase from HV as required for the slope test.

In on page 7-68, pay special attention to the polarity marks of the T-PRO input and Current Sources.

As always, confirm the test currents in Metering>Analog as shown in Figure 7.38: on page 7-57 and Figure 7.39: on page 7-58.

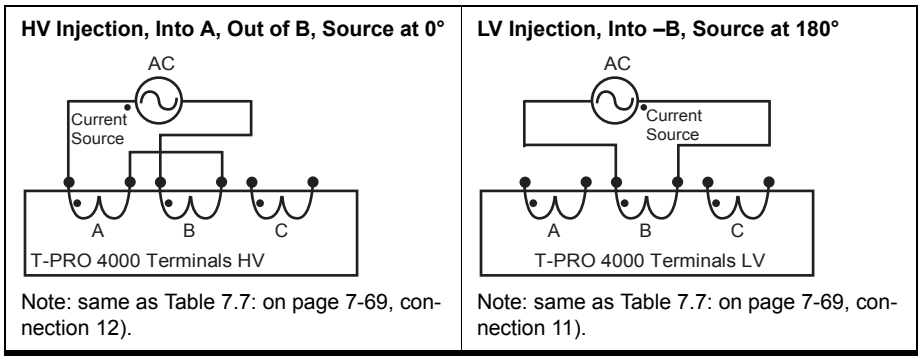


Figure 7.40: Test Connections for Single Phase Slope Testing of Our Example Transformer.

Step 4

Find the Single Phase Magnitude Correction Factor.

When we put 1.0 A into A-B of the CPC12 formulas of "Current Phase Correction Table" in Appendix L for HV in Step 3, we found that we got 1.0 A of Operating current on A-B. Since we get the full 1.0 A on the HV for 1.0 A injected, no additional magnitude correction factor is required. i.e., the correction factor is 1.0, as is also stated in "Single-Phase Correction Factor Table" on page 7-63 for a 0° connection.

On the -30° side, we found that when we put 1.0 A into CPC1 formulas for LV in Step 3, we got only 0.577 A out (i.e., 1/√3). Therefore we need to correct the current by √3 on the LV side to get back to the 1.0 A that we injected. That is, the single phase magnitude correction factor for CPC1 is √3 so we multiply by √3 as stated in "Single-Phase Correction Factor Table" on page 7-63 for a -30° connection.

In Step 1 we noted our calculated 3 Phase operating currents for IR_{min}:

The HV 3 Phase Test Current for IR_{min} = 1.69 A.

The LV 3 Phase Test Current for IR_{min} = 1.39 A.

For Single Phase testing we will apply the magnitude correction factors from "Single-Phase Correction Factor Table" on page 7-63.

Our HV Single Phase Current = 3 Phase I_{HV} * Single Phase MCF = 1.69 * 1.0 = 1.69 A.

Our LV Single Phase Current = 3 Phase I_{LV} * Single Phase MCF = 1.39 A * Ö3 = 2.41 A

From our calculations, the T-PRO differential should operate if we inject:

Input 1: 1.69A∠0° into A-B, and Input 2: 2.41A∠180° into –B.

We should get target 87 AB.

Simplified Single Phase Test Connection Suggestions

In order to simplify the single phase testing, we provide the following test connections which will always produce A-B operating currents in the T-PRO. You may use these diagrams instead of always performing single phase testing Steps 3 and 4.

You will still need to perform Step 1 to obtain your 3 phase test currents, and Step 2 to create your Net Angle Table to obtain the net angle for each Input.

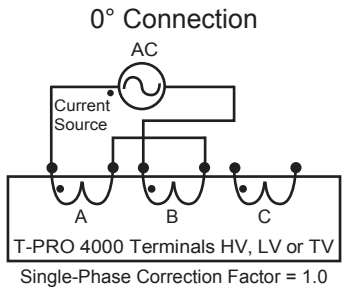
For each input in your NAT, go to column 5 and find the matching connection angle in Table 7.6: Net Angle Table. The diagrams show the test connections for every angle possibility. Table 7.6: Net Angle Table also includes the Single Phase Magnitude Correction Factor (either 1.0 or √3) to compensate and adapt your calculated 3 phase currents for single phase testing.

In our test example, Input1 is a 0° connection and Input2 is a -30° connection. On Input1 we would use Table 7.6: Net Angle Table connection number 12) and on Input2 we would use Table 7.6 connection number 11).

Note that all of the connections in Table 7.7: on page 7-69 are for A-B current into the transformer. Since 87 Slope testing simulates an external fault, you will need to add 180° to one of the current sources to simulate a through fault. It is very important to observe the location of the polarity marks shown in Table 7.6 for the current sources and T-PRO inputs.

To obtain other test phases (B-C and C-A), move all of the connections in a clockwise rotation. For example, to test phases B-C in Table 7.7: Single Phase Test Connection Suggestions for A-B: connection 11), move your test connection from B∠180° to C∠180°.

Table 7.7: Single Phase Test Connection Suggestions for A-B:



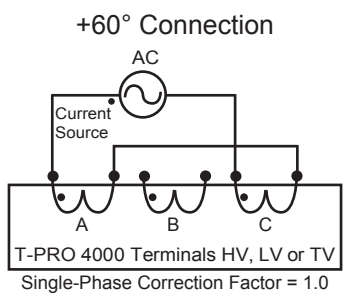
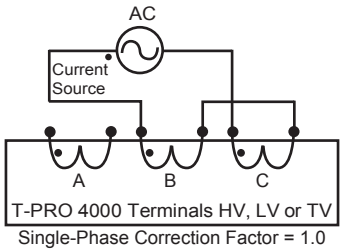


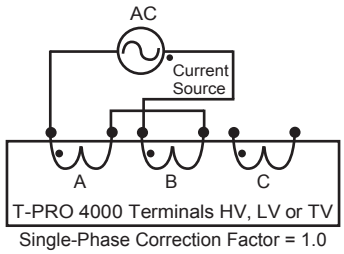
Table 7.7: Single Phase Test Connection Suggestions for A-B:

+120° Connection



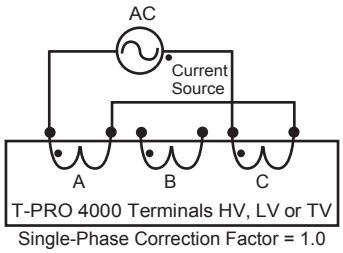
Single-Phase Correction Factor = 1.0

180° Connection



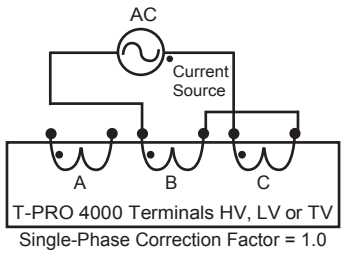
Single-Phase Correction Factor = 1.0

-120° Connection



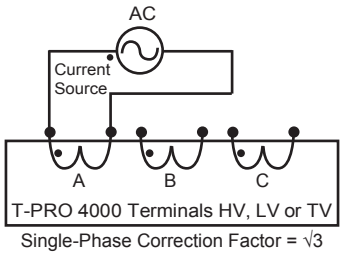
Single-Phase Correction Factor = 1.0

-60° Connection



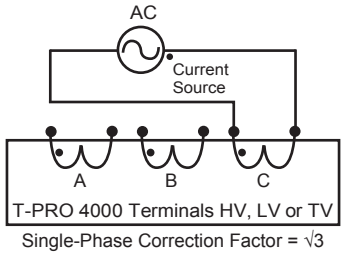
Single-Phase Correction Factor = 1.0

+30° Connection



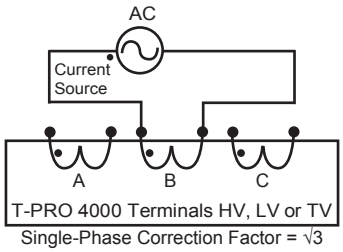
Single-Phase Correction Factor = √3

+90° Connection



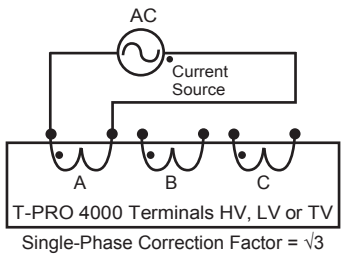
Single-Phase Correction Factor = √3

+150° Connection



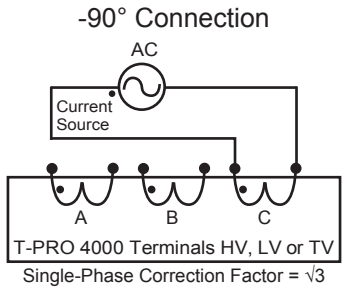
Single-Phase Correction Factor = √3

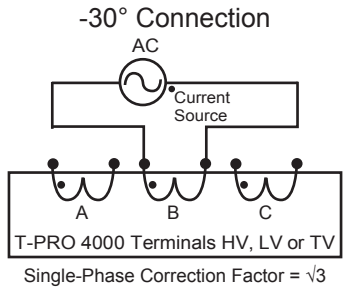
-150° Connection



Single-Phase Correction Factor = √3

Table 7.7: Single Phase Test Connection Suggestions for A-B:





8 Installation

8.1 Introduction

This section deals with the installation of the T-PRO relay when first delivered. The section covers the physical mounting, AC and DC wiring and the Communication wiring.

8.2 Physical Mounting

Standard 3U

The relay is 3 rack units or 5.25 inches high and approximately 12.9 inches deep. The standard relay is designed for a 19-inch rack. A complete mechanical drawing is shown, for details see “Mechanical Drawings” in Appendix G.

To install the relay the following is needed:

- 19 inch rack
- 4 - #10 screws

4U

The relay is 4 rack units or 7.0 inches high and approximately 12.25 inches deep. The relay is designed for a 19-inch rack. A complete mechanical drawing is shown, for details see “Mechanical Drawings” in Appendix G.

To install the relay the following is needed:

- 19 inch rack
- 4 - #10 screws

8.3 AC and DC Wiring

For details see “AC Schematic Drawing” in Appendix I and “DC Schematic Drawing” in Appendix J.

8.4 Communication Wiring

EIA-232

The relay’s serial ports (Ports 122 and 123) are configured as EIA RS-232 Data Communications Equipment (DCE) devices with female DB9 connectors. This allows them to be connected directly to a PC serial port with a standard straight-through male-to-female serial cable. Shielded cable is recommended, for pin-out see “Communication Port Details” on page 2-20.

An adapter is available for connecting an external modem to Port 123 for details see “Modem Link” on page 2-10.

RJ-45

There is one front 100BASE-T Ethernet Port 119 with RJ-45 receptacle. Use CAT5 or CAT5e straight. The rear Ethernet Ports 119 and 120 may also be configured as 100BASE-T Ethernet Ports.

Optical ST

Port 119 and port 120 in the rear panel may be configured with ST style optical connectors if desired. These are 1300 nm 100BASE-FX optical Ethernet ports. The transmit and receive connections are indicated on the rear panel. Use standard multi-mode cables with ST connectors for this interface.

USB

There is a standard USB-B connector on the front panel. This is a USB 2.0 Full Speed interface and can be connected to a PC with a standard USB peripheral cable (A style to B style).

RJ-11

The relay may have an optional internal modem. Connection to this is via the relay's Port 118 RJ-11 receptacle. A standard telephone extension cable is to be used.

IRIG-B Wiring

The relay accepts both modulated and unmodulated IRIG-B standard time signals with or without the IEEE 1344 extensions. The IRIG-B connector on the back of the relay is BNC type.

Appendix A IED Specifications

T-PRO Model 4000 Specifications		
General:	**Quantity/Specifications**	**Note**
Nominal Frequency	50 or 60 Hz	
Operate Time	12 – 25 ms typical	Including relay output operation
Power Supply	Range: 43 – 275 Vdc, 90 – 265 Vac	Power Consumption: 25 – 30 VA (ac) 25 – 30 W (dc)
Memory	Settings and records are stored in non-volatile memory	Records are stored in a circular buffer
Protection Functions:		
IEEE Device 87, 87N, 49, 50/51, 50N/51N, 24INV/DEF, 50BF, 59N, 59, 60, 81, THD, 27, 67, Temperature Control and TOEWS[1]	2 or 3 winding transformer with 5 sets of 3-phase current inputs, 1 set of 3-phase voltage inputs. 2 optional temperature inputs (4 – 20 mA dc)	Breaker-and-a-half and ring bus configuration, fault protection, monitoring, fault, temperature and trend recording
ProLogic	24 statements per setting group	5 inputs per ProLogic™ statement
Group Logic	8 (16 group logic statements per setting group)	5 inputs per group logic statement
Recording:		
Transient (fault)	96 s/c oscillography of all analog and external input digital channels	User-configurable 0.2 to 10 seconds record length and 0.1 to 2.0 seconds pre trigger record length
Trend	3 – 60 minute sample logging of MW, MVAR, I, ambient temperature and loss of life. Trend recording from 30 up to 600 days	When “trend auto save” is enabled, a compressed trend record is created once the trend period is completed
Sequence of Events Recorder	250 events circular log with 1ms resolution	When event auto save is enabled, a compressed event record is created every 250 events.
Record Capacity	Up to 150 sec transient records, trend and event records	

T-PRO Model 4000 Specifications

Input & Output:		
Analog Voltage Inputs 1 set of 3-phase voltage inputs	Nominal Voltage - across input channel Full Scale/Continuous Maximum Over-scale Thermal Rating Burden	Vn = 69 Vrms (120 Vrms L-L) 2x Vn = 138 Vrms (240 Vrms L-L) 4x Vn = 276 Vrms (480 Vrms L-L) for 3 seconds 3x Vn = 207 Vrms (360 Vrms L-L) for 10 seconds <0.03VA @ Vn
Analog Current Inputs 5 sets of 3-phase current inputs (15 current channels)	Nominal Current Full Scale/Continuous Maximum full-scale rating Thermal rating Burden	In = 1 Arms or 5 Arms 3x In = 3 Arms or 15 Arms 40x In for 1 second symmetrical 400 Arms for 1 second <0.25 VA @ 5 Arms <0.10 VA @ 1 Arms
Optional Temperature Inputs, Ambient and Top Oil	2, 4 – 20 mA current loops	External temperature sensor can be self-powered or from T-PRO relay. Unregulated 30 Vdc supply – output 40 mA @ 24 Vdc
Amplitude measurement accuracy	+/-0.5% for 54 to 66 Hz +/-0.5% for 44 to 56 Hz	
Analog Sampling Rate	96 samples/cycle for recording 8 samples/cycle for protection	Records up to 25th harmonic
External Inputs (digital)	9 isolated inputs (3U chassis) 20 isolated inputs (4U chassis)	Optional 48, 110/125 or 220/250 Vdc nominal, externally wetted
Isolation	2 KV optical isolation	
External Input Turn-on Voltage	48 Vdc range = 27 to 40 Vdc 125 Vdc = 75 to 100 Vdc 250 Vdc = 150 to 200 Vdc, 60% to 80% of nominal	Specified voltages are over full ambient temperature range.
Output Relays (contacts)	14 programmable outputs (3U chassis) and 1 relay inoperative contact (N.C.) 21 programmable outputs (4U chassis) and 1 relay inoperative contact (N.C.)	Externally wetted Make: 30 A as per IEEE C37.90 Carry: 8 A Break: 0.9 A at 125 Vdc resistive 0.35 A at 250 Vdc resistive
Virtual Inputs	30 Virtual Inputs	
Interface & Communication:		
Front Display	240 x 128 pixels graphics LCD	
Front Panel Indicators	16 LEDs: 11 programmable and 5 fixed	Target (11programmable), Relay Functional, IRIG-B Functional, Service Required, Test Mode , Alarm
Front User Interface	USB port and 100BASE-T Ethernet port	Full Speed USB 2.0, RJ-45
Rear User Interface	LAN Port 1: 100BASE copper or optical 1300 nm LAN Port 2: 100BASE optical 1300 nm Two Serial RS-232 ports to 115 kbd	Copper: RJ-45, 100BASE-T Optical: 100BASE-FX, Multimode ST style connector Com port can support external modem
Internal Modem	33.6 Kbps, V.32 bis	Optional internal modem

T-PRO Model 4000 Specifications

SCADA Interface	IEC 61850, DNP3 (RS-232 or Ethernet) or Modbus (RS-232)	Rear port
Time Sync	IRIG-B, BNC connector B003,B004,B123 and B124 Time Codes	Modulated or unmodulated, auto-detect
Self Checking/Relay Inoperative	1 contact	Closed when relay inoperative
Environmental:		
Ambient Temperature Range	-40C to 85C for 16 hours -40C to 70C continuous	IEC 60068-2-1/IEC 60068-2-2 LCD contrast impaired for temperatures below -20C and above 70 C
Humidity	Up to 95% without condensation	IEC 60068-2-30
Insulation Test (Hi-Pot)	Power supply, analog inputs, external inputs, output contacts – 2 kVrms, 50/60 Hz, 1 minute	IEC 60255-5, ANSI/IEEE C37.90
Electrical Fast Transient	Tested to level 4 – 4.0 kV 2.5/5 kHz on power and I/O lines	ANSI/IEEE C37.90.1, IEC/EN 60255-22-4, IEC 61000-4-4 Level 4
Oscillatory Transient	Test level = 2.5 kV	ANSI/IEEE C37.90.1, IEC/EN 60255-22-1, IEC61000-4-12 Level 3
RFI Susceptibility	10 V/m modulated, 35 V/unmodulated	ANSI/IEEE C37.90.2, IEC 60255-22-3, IEC 61000-4-3 Level 3
Conducted RF Immunity	150 kHz to 80 MHz	IEC 60255-22-6 / IEC 61000-4-6 Level 3
Shock and Bump	5 g and 15 g	IEC 60255-21-2, IEC/EN 60068-2-27: Class 1
Sinusoidal Vibration	1g, 10 Hz to 150 Hz, 1.0 octave/min, 40 sweeps	IEC/EN 60255-21-1, IEC/EN 60068-26, Class 1
Voltage Interruptions	200 ms interrupt	IEC 60255-11 / IEC 61000-4-11
Physical:		
Weight	3U chassis - 10.4 Kg/23 lbs 4U chassis - 12.1 kg /26.6 lbs	
Dimensions	3U chassis: 13.2 cm height x 48.26 cm width rack mount x 32.8 cm depth 4U chassis 17.7 cm x 48.3 cm x 32.8 cm	5.2 height x 19 width rack mount x 12.9 depth 6.93" x 19 x 12.9
Time Synchronization and Accuracy		
External Time Source	Synchronized using IRIG-B input (modulated or unmodulated) auto detect	Upon the loss of an external time source, the relay maintains time with a maximum 160 seconds drift per year at a constant temperature of 25C. The relay can detect loss of re-establishment of external time source and automatically switch between internal and external time.
Synchronization Accuracy	Sampling clocks synchronized with the time source (internal or external).	
Overall T-PRO Accuracies		

T-PRO Model 4000 Specifications

Current	±2.5% of inputs from 0.1 to 1.0 x nominal current (In)
	±1.0% of inputs from 1.0 to 40.0 x nominal current (In)
Voltage	±1.0% of inputs from 0.01 to 2.0 x nominal voltage (Vn)
Differential Element	±5.0% of set value IOmin from 0.10 to 1.0 per unit (pu)
Directional Phase Angle	±2.5% or > 2.0 of set value from 0.01 to 360.0
Frequency Elements	±0.001 Hz (fixed level)
	±0.05 Hz (df/dt)
Inverse Overcurrent Timers	±2.5% or 1 cycle of selected curve

T-PRO Model 4000 Specifications

Detailed Environmental Tests

Test	Description		Test Level
	Type Test	Test Points	
FCC Part 15	RF emissions	Enclosure ports	Class A: 30 - 1000 MHz
	Conducted emissions	ac/dc power ports	Class A: 0.15 - 30 MHz
IEC/EN 60255-25	RF emissions	Enclosure ports	Class A: 30 - 1000 MHz
	Conducted emissions	ac/dc power ports	Class A: 0.15 - 30 MHz
IEC/EN 61000-3-2	Power line harmonics	ac power port	Class D: max.1.08, 2.3, 0.43
			1.14, 0.3, 0.77, 0.23 A.... for 2nd to nth harmonic
		dc power port	N/A
IEC/EN 61000-3-3	Power line fluctuations	ac power port	THD/ 3%; Pst <1., Plt < 0.65
		dc power port	N/A
IEC/EN 61000-4-2	ESD	Enclosure contact	+/- 6 kV
IEC/EN 60255-22-2		Enclosure air	+/- 8 kV
IEEE C37.90.3	ESD	Enclosure contact	+/- 8 kV
		Enclosure air	+/- 15 kV
IEC/EN 61000-4-3	Radiated RFI	Enclosure ports	10 V/m: 80 - 1000 MHz
IEC/EN 60255-22-3			
IEEE C37.90.2	Radiated RFI	Enclosure ports	35 V/m: 25 - 1000 MHz
IEC/EN 61000-4-4	Burst (fast transient)	Signal ports	+/- 4 kV @2.5 kHz
IEC/EN 60255-22-4		ac power port	+/- 4 kV

T-PRO Model 4000 Specifications

Detailed Environmental Tests

IEEE C37.90.1		dc power port	+/- 4 kV
		Earth ground ports	+/- 4 kV
IEC/EN 61000-4-5	Surge	Communication ports	+/- 1 kV L-PE
IEC/EN 60255-22-5		Signal ports	+/- 4 kV L-PE, +/-2 kV L-L
		ac power port	+/- 4 kV L-PE, +/-2 kV L-L
		dc power port	+/- 4 kV L-PE, +/-2 kV L-L
IEC/EN 61000-4-6	Induced (conducted) RFI	Signal ports	10 Vrms: 0.150 - 80 MHz
IEC/EN 60255-22-6		ac power port	10 Vrms: 0.150 - 80 MHz
		dc power port	10 Vrms: 0.150 - 80 MHz
		Earth ground ports	10 Vrms: 0.150 - 80 MHz
IEC/EN 60255-22-7	Power frequency	Binary input ports: Class A	Differential = 150 Vrms
			Common = 300 Vrms
IEC/EN 61000-4-8	Magnetic leld	Enclosure ports	40 A/m continuous, 1000 A/m for 1 s
IEC/EN 61000-4-11	Voltage dips & interrupts	ac power port	30% for 1 period, 60% for 50 periods
			100% for 5 periods, 100% for 50 periods
		dc power port	30% for 0.1 s, 60% for 0.1 s,
			100% for 0.05 s
IEC 60255-11	Voltage dips & interrupts	dc power port	100% reduction for up to 200 ms
IEC/EN 61000-4-12	Damped oscillatory	Communication ports	1.0 kV Common, 0 kV Diff
IEC/EN 60255-22-1		Signal ports	2.5 kV Common, 1 kV Diff
		ac power port	2.5 kV Common, 1 kV Diff
		dc power port	2.5 kV Common, 1 kV Diff
IEEE C37.90.1	Oscillatory	Signal ports	2.5 kV Common, 0 kV Diff
		ac power port	2.5 kV Common, 0 kV Diff
		dc power port	2.5 kV Common, 0 kV Diff
IEC/EN 61000-4-16	Mains frequency voltage	Signal ports	30 V continuous, 300 V for 1s
		ac power port	30 V continuous, 300 V for 1s
IEC/EN 61000-4-17	Ripple on dc power supply	dc power port	10%

Note:The T-PRO 4000 is available with 5 or 1 amp current input. All current specifications change accordingly.
[1]TOEWS and Transformer asset monitoring require the optional temperature inputs.

A.1 Frequency Element Operating Time Curves

Figure A.2: Time delay Error at .2 Seconds, Figure A.3: Time Delay Error at 1 Second and Figure A.4: Time Delay Error at 10 Seconds show operating times for the T-PRO frequency rate of change elements at different time delay settings and rate of change settings.

The diagrams show operating times at each test point including output contact operate time. Operating times are the same for both 50 Hz and 60 Hz.

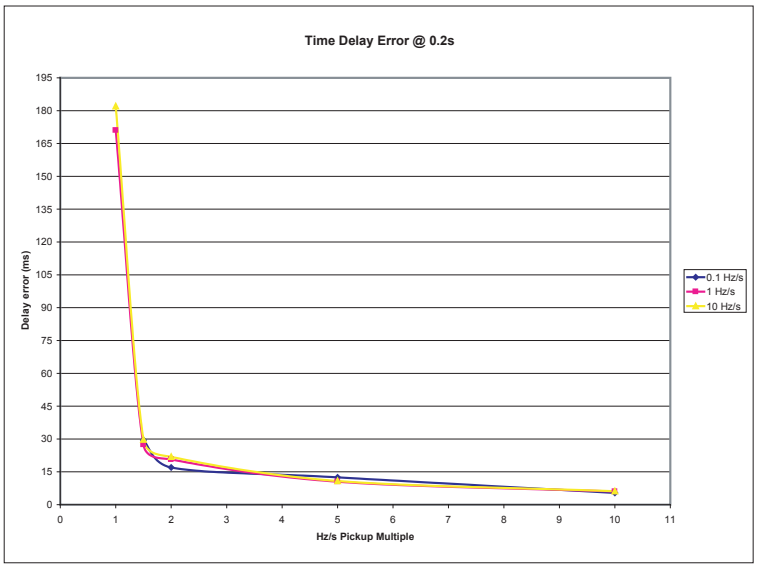


Figure A.2: Time delay Error at .2 Seconds

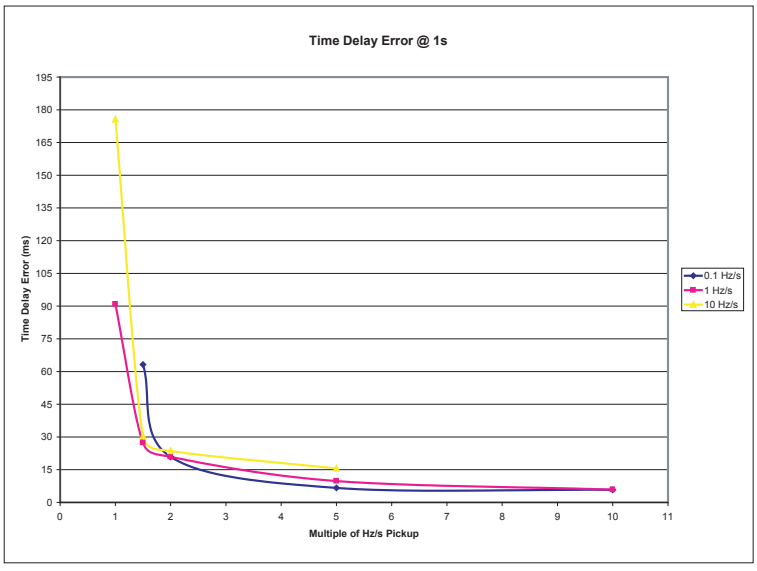


Figure A.3: Time Delay Error at 1 Second

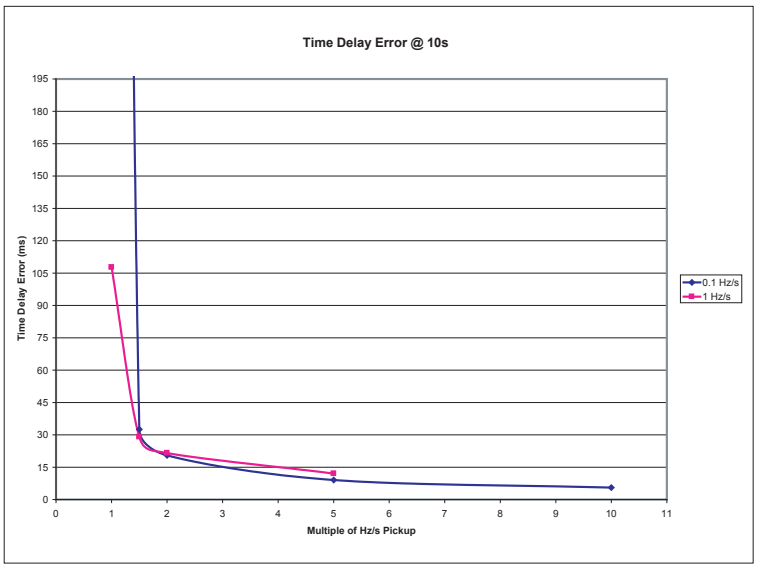


Figure A.4: Time Delay Error at 10 Seconds

Appendix B IED Settings and Ranges

When a setting has been completed in Offliner Settings software, it can be printed along with the ranges available for these settings. This is a view only option; to change the settings you must go back into the particular setting that you wish to change. The summary is a quick way to view all the settings in a compact form.

The top part of the settings summary contains all the information from the Relay Identification screen.

The setting summary provides a list of all the current and voltage analog input quantity names used for protection and recording. External Inputs and Output contact names are also identified on this summary.

T-PRO Settings Summary - Setting Group 1 [Setting Group 1]			
Name	**Symbol/Value**	**Unit**	**Range**
Relay Identification			
Settings Version	402		
Ignore Serial Number	No		
Serial Number	TPRO-4000-000000-01		
Unit ID	UnitID		
Nominal CT Secondary Current	5	A	1A or 5A
Nominal System Frequency	60	Hz	50Hz or 60Hz
Standard I/O	9 External Inputs and 14 Output Contacts		
Optional I/O	Not Installed		
Comments	Comments		
Setting Name	Settings Name		
Date Created-Modified	2013-06-20 11:00:00		
Station Name	Station Name		
Station Number	1		
Location	Location		
Bank Name	Bank Name		
Analog Input Names			
VA	Voltage A		
VB	Voltage B		
VC	Voltage C		
IA1	IA1		
IB1	IB1		
IC1	IC1		

IA2	IA2		
IB2	IB2		
IC2	IC2		
IA3	IA3		
IB3	IB3		
IC3	IC3		
IA4	IA4		
IB4	IB4		
IC4	IC4		
IA5	IA5		
IB5	IB5		
IC5	IC5		
Temperature D.C. 1	DC1		
Temperature D.C. 2	DC2		
External Input Names			
1	EI Spare 1		
2	EI Spare 2		
3	EI Spare 3		
4	EI Spare 4		
5	EI Spare 5		
6	EI Spare 6		
7	EI Spare 7		
8	EI Spare 8		
9	EI Spare 9		
Output Contact Names			
Output 1	Out Spare 1		
Output 2	Out Spare 2		
Output 3	Out Spare 3		
Output 4	Out Spare 4		
Output 5	Out Spare 5		
Output 6	Out Spare 6		
Output 7	Out Spare 7		
Output 8	Out Spare 8		
Output 9	Out Spare 9		
Output 10	Out Spare 10		
Output 11	Out Spare 11		
Output 12	Out Spare 12		
Output 13	Out Spare 13		
Output 14	Out Spare 14		
Virtual Input Names			

1	Virtual Input 1		
2	Virtual Input 2		
3	Virtual Input 3		
4	Virtual Input 4		
5	Virtual Input 5		
6	Virtual Input 6		
7	Virtual Input 7		
8	Virtual Input 8		
9	Virtual Input 9		
10	Virtual Input 10		
11	Virtual Input 11		
12	Virtual Input 12		
13	Virtual Input 13		
14	Virtual Input 14		
15	Virtual Input 15		
16	Virtual Input 16		
17	Virtual Input 17		
18	Virtual Input 18		
19	Virtual Input 19		
20	Virtual Input 20		
21	Virtual Input 21		
22	Virtual Input 22		
23	Virtual Input 23		
24	Virtual Input 24		
25	Virtual Input 25		
26	Virtual Input 26		
27	Virtual Input 27		
28	Virtual Input 28		
29	Virtual Input 29		
30	Virtual Input 30		
Setting Group Names			
Setting Group 1	Setting Group 1		
Setting Group 2	Setting Group 2		
Setting Group 3	Setting Group 3		
Setting Group 4	Setting Group 4		
Setting Group 5	Setting Group 5		
Setting Group 6	Setting Group 6		
Setting Group 7	Setting Group 7		
Setting Group 8	Setting Group 8		
Setting Group 1 [Setting Group 1]			

Setting Group Comments: Default Settings.			
Nameplate Data			
Transformer 3 Phase Capacity	100.0	MVA	1.0 to 2000.0
Transformer Winding	3		2 or 3
Tap Changer Range	0	%	-100 to 100
Normal Loss of Life Hot Spot Temp.	110.0	°C	70.0 to 200.0
Transformer Temperature Rise	65	°C	
Transformer Cooling Method	Self cooled		
Temp. Rise Hot Spot (TRiseHS)	25.00	°C	-
Temp. Rise Top Oil (TRiseTop)	55.00	°C	-
Temp. Rise Time Const. Hot Spot (TauHS)	0.08	hours	-
Temp. Rise Time Const. Top Oil (TauTop)	3.00	hours	-
Ratio of Load Loss to Iron Loss (R)	3.20	-	-
Hot Spot Temp. Exponent (m)	0.80	-	-
Top Oil Temp. Exponent (n)	0.80	-	-
Winding			
Voltage Input Connection			
PT Turns Ratio	2000.0	-	1.0 to 10000.0
Location	HV		HV or LV
Transformer NamePlate			
HV: (as PT Source)			
Voltage	230.0	kV	115.0 to 1000.0
Connection	Y		Delta or Y
Phase	0°		
LV:			
Voltage	115.0	kV	13.8 to 230.0
Connection	Y		Delta or Y
Phase	0°		DY, YD, YY connection: 0°, 30°, 60°, 90°, 120°, 150°, 180°, -150°, -120°, -90°, -60°, -30° DD connection: 0°, 60°, 120°, 180°, -120°, -60°
TV:			
Voltage	13.8	kV	1.0 to 115.0
Connection	Y		Delta or Y
Phase	0°		DY, YD, YY connection: 0°, 30°, 60°, 90°, 120°, 150°, 180°, -150°, -120°, -90°, -60°, -30° DD connection: 0°, 60°, 120°, 180°, -120°, -60°
CT Connections			
Current Input 1			

Winding	HV		HV, LV, TV, NC
Connection	Y		Delta or Y
Phase	0°		Y connection: 0°, 60°, 120°, 180°, -120°, -60° Delta connection: 30°, 90°, 150°, -150°, -90°, -30°
Turns Ratio	100.00	:1	1.00 to 50000.00
External Input Selection	<Not Used>		Not Used, EI 1 to EI 9
Current Input 2			
Winding	LV		HV, LV, TV, NC
Connection	Y		Delta or Y
Phase	0°		Y connection: 0°, 60°, 120°, 180°, -120°, -60° Delta connection: 30°, 90°, 150°, -150°, -90°, -30°
Turns Ratio	200.00	:1	1.00 to 50000.00
External Input Selection	<Not Used>		Not Used, EI 1 to EI 9
Current Input 3			
Winding	TV		HV, LV, TV, NC
Connection	Y		Delta or Y
Phase	0°		Y connection: 0°, 60°, 120°, 180°, -120°, -60° Delta connection: 30°, 90°, 150°, -150°, -90°, -30°
Turns Ratio	200.00	:1	1.00 to 50000.00
External Input Selection	<Not Used>		Not Used, EI 1 to EI 9
Current Input 4			
Winding	NC		HV, LV, TV, NC
Connection	Y		Delta or Y
Phase	0°		Y connection: 0°, 60°, 120°, 180°, -120°, -60° Delta connection: 30°, 90°, 150°, -150°, -90°, -30°
Turns Ratio	450.00	:1	1.00 to 50000.00
External Input Selection	<Not Used>		Not Used, EI 1 to EI 9
Current Input 5			
Winding	NC		HV, LV, TV, 51N/87N, 87N Auto, NC
Connection	Y		Delta or Y
Phase	0°		Y connection: 0°, 60°, 120°, 180°, -120°, -60° Delta connection: 30°, 90°, 150°, -150°, -90°, -30°

Turns Ratio	4000.00	:1	1.00 to 50000.00
External Input Selection	<Not Used>		Not Used, EI 1 to EI 9
Ambient Temperature Scaling			
Max Valid Temperature	50.0	°C	-40.0 to 50.0
Min Valid Temperature	-50.0	°C	-50.0 to 40.0
Max Correlating Current Value	20.00	mA	5.00 to 20.00
Min Correlating Current Value	4.00	mA	4.00 to 19.00
Top Oil Temperature Scaling			
Top Oil	Calculated		
Max Valid Temperature	200.0	°C	-30.0 to 200.0
Min Valid Temperature	-40.0	°C	-50.0 to 190.0
Max Correlating Current Value	20.00	mA	5.00 to 20.00
Min Correlating Current Value	4.00	mA	4.00 to 19.00
Record Length			
Fault Record Length	0.5	s	0.2 to 10.0
Prefault Time	0.20	s	0.10 to 2.00 or to (Fault Record Length - 0.10) whichever lesser
Thermal Logging	Disabled		
Trend Sample Rate	3	minutes/sample	3 to 60
Event Auto Save	Disabled		
Protection Summary			
87	Disabled		
87N-HV	Disabled		
87N-LV	Disabled		
87N-TV	Disabled		
49-1	OFF		
49-2	OFF		
49-3	OFF		
49-4	OFF		
49-5	OFF		
49-6	OFF		
49-7	OFF		
49-8	OFF		
49-9	OFF		
49-10	OFF		
49-11	OFF		
49-12	OFF		
TOEWS	Disabled		
24INV	Disabled		

24DEF-1	Disabled		
24DEF-2	Disabled		
59N	Disabled		
27-1	Disabled		
27-2	Disabled		
60	Disabled		
81-1	Disabled		
81-2	Disabled		
81-3	Disabled		
81-4	Disabled		
50BF-1	Disabled		
50BF-2	Disabled		
50BF-3	Disabled		
50BF-4	Disabled		
50BF-5	Disabled		
50-HV	Disabled		
51-HV	Disabled		
50-LV	Disabled		
51-LV	Disabled		
50-TV	Disabled		
51-TV	Disabled		
51ADP	Disabled		
50N-HV	Disabled		
51N-HV	Disabled		
50N-LV	Disabled		
51N-LV	Disabled		
50N-TV	Disabled		
51N-TV	Disabled		
59-1	Disabled		
59-2	Disabled		
67	Disabled		
THD	Disabled		
Through Fault Monitor	Disabled		
87 - Differential			
87	Disabled		
IOmin	0.30	pu	0.10 to 1.00
Input 1	0.75	A	-
Input 2	0.75	A	-
Input 3	0.75	A	-
Input 4	N/A		

Input 5	N/A		
IRs	5.00	pu	1.00 to 50.00
S1	30.00	%	6.00 to 100.00
S2	100.00	%	30.00 to 200.00
High Current Setting	10.00	pu	0.90 to 100.00
I2 Cross-Blocking	Enabled		
I2_2nd / I_fund Ratio	0.20	-	0.05 to 1.00
I5	Disabled		
I_5th / I_fund Ratio	0.30	-	0.05 to 1.00
87N - Neutral Differential			
87N-HV	Disabled		
IOmin	0.30	pu	0.10 to 1.00
IOmin	0.75	A	-
IRs	5.00	pu	1.00 to 50.00
S1	30.00	%	6.00 to 100.00
S2	100.00	%	30.00 to 200.00
Neutral CT Turns Ratio	100.00	:1	1.00 to 50000.00
87N-LV	Disabled		
IOmin	0.30	pu	0.10 to 1.00
IOmin	0.75	A	-
IRs	5.00	pu	1.00 to 50.00
S1	30.00	%	6.00 to 100.00
S2	100.00	%	30.00 to 200.00
Neutral CT Turns Ratio	200.00	:1	1.00 to 50000.00
87N-TV	Disabled		
IOmin	0.30	pu	0.10 to 1.00
IOmin	6.28	A	-
IRs	5.00	pu	1.00 to 50.00
S1	30.00	%	6.00 to 100.00
S2	100.00	%	30.00 to 200.00
Neutral CT Turns Ratio	200.00	:1	1.00 to 50000.00
49-1 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0

Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
49-2 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
49-3 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
49-4 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR

49-5 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
49-6 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
49-7 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
49-8 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00

Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
49-9 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
49-10 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
49-11 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00

Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
49-12 - Thermal Overload			
Current Input Switch	OFF		OFF, HV, LV, TV
Pickup	1.10	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay (Tp1)	0.00	s	0.00 to 1800.00
Dropout Delay (Td1)	0.00	s	0.00 to 1800.00
Temperature Input Switch	OFF		OFF, Hot Spot, Top Oil
Pickup	120.0	°C	70.0 to 200.0
Hysteresis	1.0	°C	0.0 to 10.0
Pickup Delay (Tp2)	0.01	hours	0.00 to 24.00
Dropout Delay (Td2)	0.00	hours	0.00 to 24.00
Logic Gate Switch	OR		AND, OR
TOEWS (Transformer Overload Early Warning System)			
TOEWS	Disabled		
THS (Temperature Hot Spot) Trip Setting	150.0	°C	70.0 to 200.0
THS To Start LOL (Loss of Life) Calculation	140.0	°C	70.0 to 200.0
LOL Trip Setting	2.0	days	0.5 to 100.0
24INV - Inverse Time			
24INV	Disabled		
K	0.10	-	0.10 to 100.00
Pickup	1.20	pu	1.00 to 2.00
Reset Time	50.00	s	0.05 to 9999.99
24DEF Definite Time Delay			
24DEF-1	Disabled		
Pickup	1.10	pu	1.00 to 2.00
Pickup Delay	2.00	s	0.05 to 9999.99
24DEF-2	Disabled		
Pickup	1.20	pu	1.00 to 2.00
Pickup Delay	5.00	s	0.05 to 9999.99
59N - Zero Sequence Overvoltage			
59N	Disabled		
3V0 Pickup	10.00	V	5.00 to 150.00
Curve Type	IEC standard inverse		

TMS	1.00	-	0.01 to 10.00
A	0.1400	-	-
B	0.0000	-	-
p	0.02	-	-
TR	13.50	-	0.10 to 100.00
27 - Undervoltage			
27-1	Disabled		
Gate Switch	AND		OR, AND
Pickup	25.0	V	1.0 to 120.0
Pickup Delay	5.00	s	0.00 to 99.99
27-2	Disabled		
Gate Switch	AND		OR, AND
Pickup	25.0	V	1.0 to 120.0
Pickup Delay	5.00	s	0.00 to 99.99
60 - Loss of Potential Alarm			
60	Disabled		
81 - Over/Under Frequency			
81-1	Disabled		Disabled, Fixed Level, Rate of Change
Pickup	57.600	Hz	[50.000, 59.995] or [60.005, 70.000]
Pickup Delay	2.00	s	0.05 to 99.99
81-2	Disabled		Disabled, Fixed Level, Rate of Change
Pickup	57.000	Hz	[50.000, 59.995] or [60.005, 70.000]
Pickup Delay	2.00	s	0.05 to 99.99
81-3	Disabled		Disabled, Fixed Level, Rate of Change
Pickup	61.800	Hz	[50.000, 59.995] or [60.005, 70.000]
Pickup Delay	2.00	s	0.05 to 99.99
81-4	Disabled		Disabled, Fixed Level, Rate of Change
Pickup	62.400	Hz	[50.000, 59.995] or [60.005, 70.000]
Pickup Delay	2.00	s	0.05 to 99.99
50BF - Breaker Failure			
50BF-1	Disabled		
Pickup Delay1	0.20	s	0.01 to 99.99
Pickup Delay2	0.20	s	0.01 to 99.99
Breaker Current Pickup	1.00	A	0.10 to 50.00

Breaker Status	<Disabled>		Disabled, EI 1 to EI 9, PL 1 to PL 24
50BF-2	Disabled		
Pickup Delay1	0.20	s	0.01 to 99.99
Pickup Delay2	0.20	s	0.01 to 99.99
Breaker Current Pickup	1.00	A	0.10 to 50.00
Breaker Status	<Disabled>		Disabled, EI 1 to EI 9, PL 1 to PL 24
50BF-3	Disabled		
Pickup Delay1	0.20	s	0.01 to 99.99
Pickup Delay2	0.20	s	0.01 to 99.99
Breaker Current Pickup	1.00	A	0.10 to 50.00
Breaker Status	<Disabled>		Disabled, EI 1 to EI 9, PL 1 to PL 24
50BF-4	Disabled		
Pickup Delay1	0.20	s	0.01 to 99.99
Pickup Delay2	0.20	s	0.01 to 99.99
Breaker Current Pickup	1.00	A	0.10 to 50.00
Breaker Status	<Disabled>		Disabled, EI 1 to EI 9, PL 1 to PL 24
50BF-5	Disabled		
Pickup Delay1	0.20	s	0.01 to 99.99
Pickup Delay2	0.20	s	0.01 to 99.99
Breaker Current Pickup	1.00	A	0.10 to 50.00
Breaker Status	<Disabled>		Disabled, EI 1 to EI 9, PL 1 to PL 24
50/51 - Phase Overcurrent: HV			
50-HV	Disabled		
Pickup	10.00	pu	0.10 to 100.00
Pickup Delay	1.00	s	0.00 to 99.99
51-HV	Disabled		
Pickup	1.50	pu	0.05 to 5.00
Curve Type	IEC standard inverse		
TMS	1.00	-	0.01 to 10.00
A	0.1400	-	-
B	0.0000	-	-
p	0.02	-	-
TR	13.50	-	0.10 to 100.00
51ADP	Disabled		
Multiple of Normal Loss of Life	1.0	-	0.5 to 512.0
50/51 - Phase Overcurrent: LV			
50-LV	Disabled		
Pickup	10.00	pu	0.10 to 100.00

Pickup Delay	1.00	s	0.00 to 99.99
51-LV	Disabled		
Pickup	1.50	pu	0.05 to 5.00
Curve Type	IEC standard inverse		
TMS	1.00	-	0.01 to 10.00
A	0.1400	-	-
B	0.0000	-	-
p	0.02	-	-
TR	13.50	-	0.10 to 100.00
50/51 - Phase Overcurrent: TV			
50-TV	Disabled		
Pickup	10.00	pu	0.10 to 100.00
Pickup Delay	1.00	s	0.00 to 99.99
51-TV	Disabled		
Pickup	1.50	pu	0.05 to 5.00
Curve Type	IEC standard inverse		
TMS	1.00	-	0.01 to 10.00
A	0.1400	-	-
B	0.0000	-	-
p	0.02	-	-
TR	13.50	-	0.10 to 100.00
50N/51N - Neutral Overcurrent: HV			
50N-HV	Disabled		
Pickup	5.00	A	0.25 to 50.00
Pickup Delay	1.00	s	0.00 to 99.99
51N-HV	Disabled		
Pickup	1.00	A	0.25 to 50.00
Curve Type	IEC standard inverse		
TMS	1.00	-	0.01 to 10.00
A	0.1400	-	-
B	0.0000	-	-
p	0.02	-	-
TR	13.50	-	0.10 to 100.00
50N/51N - Neutral Overcurrent: LV			
50N-LV	Disabled		
Pickup	5.00	A	0.25 to 50.00
Pickup Delay	1.00	s	0.00 to 99.99
51N-LV	Disabled		
Pickup	1.00	A	0.25 to 50.00
Curve Type	IEC standard inverse		

TMS	1.00	-	0.01 to 10.00
A	0.1400	-	-
B	0.0000	-	-
p	0.02	-	-
TR	13.50	-	0.10 to 100.00
50N/51N - Neutral Overcurrent: TV			
50N-TV	Disabled		
Pickup	5.00	A	0.25 to 50.00
Pickup Delay	1.00	s	0.00 to 99.99
51N-TV	Disabled		
Pickup	1.00	A	0.25 to 50.00
Curve Type	IEC standard inverse		
TMS	1.00	-	0.01 to 10.00
A	0.1400	-	-
B	0.0000	-	-
p	0.02	-	-
TR	13.50	-	0.10 to 100.00
59 - Overvoltage			
59-1	Disabled		
Gate Switch	OR		OR, AND
Pickup	70.0	V	1.0 to 138.0
Pickup Delay	5.00	s	0.00 to 99.99
59-2	Disabled		
Gate Switch	OR		OR, AND
Pickup	70.0	V	1.0 to 138.0
Pickup Delay	5.00	s	0.00 to 99.99
67 - Directional Overcurrent			
67	Disabled		
Pickup	1.50	pu	0.05 to 5.00
Curve Type	IEC standard inverse		
TMS	1.00	-	0.01 to 10.00
A	0.1400	-	-
B	0.0000	-	-
p	0.02	-	-
TR	13.50	-	0.10 to 100.00
Alpha	135.0	deg	-179.9 to 180.0
Beta	150.0	deg	0.1 to 360.0
67N - Directional Earth Fault			
67N	Disabled		
Pickup	5.00	A	0.25 to 50.00

Curve Type	IEC standard inverse		
TMS	1.00		0.01 to 10.00
A	0.1400		
B	0.0000		
p	0.02		
TR	13.50		0.10 to 100.00
Alpha	135.0	deg	-179.9 to 180.0
Beta	150.0	deg	0.1 to 360.0
THD - Total Harmonic Distortion			
THD	Disabled		
Pickup	10.0	%	5.0 to 100.0
Through Fault Monitor			
Through Fault Monitor	Disabled		
Input Current	HV		HV, LV, TV
Pickup Level	1.20	pu	0.10 to 20.00
Hysteresis	0.02	pu	0.00 to 1.00
Pickup Delay	0.00	s	0.00 to 99.99
Dropout Delay	0.00	s	0.00 to 99.99
I*I*t Alarm Limit	1000.0	kA*kA*s	0.1 to 9999.9
2nd Harmonics Blocking	Disabled		
Pickup Delay	0.00	s	0.00 to 99.99
Dropout Delay	0.00	s	0.00 to 99.99
PL 1 [ProLogic 1]			
ProLogic 1	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 2 [ProLogic 2]			
ProLogic 2	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00

Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 3 [ProLogic 3]			
ProLogic 3	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 4 [ProLogic 4]			
ProLogic 4	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 5 [ProLogic 5]			
ProLogic 5	Disabled		

Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 6 [ProLogic 6]			
ProLogic 6	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 7 [ProLogic 7]			
ProLogic 7	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		

PL 8 [ProLogic 8]			
ProLogic 8	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 9 [ProLogic 9]			
ProLogic 9	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 10 [ProLogic 10]			
ProLogic 10	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		

Operator 5			
Input E	<Unused = 0>		
PL 11 [ProLogic 11]			
ProLogic 11	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 12 [ProLogic 12]			
ProLogic 12	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 13 [ProLogic 13]			
ProLogic 13	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		

Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 14 [ProLogic 14]			
ProLogic 14	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 15 [ProLogic 15]			
ProLogic 15	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 16 [ProLogic 16]			
ProLogic 16	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		

Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 17 [ProLogic 17]			
ProLogic 17	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 18 [ProLogic 18]			
ProLogic 18	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 19 [ProLogic 19]			
ProLogic 19	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		

Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 20 [ProLogic 20]			
ProLogic 20	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 21 [ProLogic 21]			
ProLogic 21	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 22 [ProLogic 22]			
ProLogic 22	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00

Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 23 [ProLogic 23]			
ProLogic 23	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
PL 24 [ProLogic 24]			
ProLogic 24	Disabled		
Pickup Delay	0.00	s	0.00 to 999.00
Dropout Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 1 [Group Logic 1]			
Group Logic 1	Disabled		

Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 2 [Group Logic 2]			
Group Logic 2	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 3 [Group Logic 3]			
Group Logic 3	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		

GL 4 [Group Logic 4]			
Group Logic 4	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 5 [Group Logic 5]			
Group Logic 5	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 6 [Group Logic 6]			
Group Logic 6	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		

Operator 5			
Input E	<Unused = 0>		
GL 7 [Group Logic 7]			
Group Logic 7	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 8 [Group Logic 8]			
Group Logic 8	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 9 [Group Logic 9]			
Group Logic 9	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		

Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 10 [Group Logic 10]			
Group Logic 10	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 11 [Group Logic 11]			
Group Logic 11	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 12 [Group Logic 12]			
Group Logic 12	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		

Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 13 [Group Logic 13]			
Group Logic 13	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 14 [Group Logic 14]			
Group Logic 14	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 15 [Group Logic 15]			
Group Logic 15	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		

Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		
GL 16 [Group Logic 16]			
Group Logic 16	Disabled		
Setting Group to Activate	<none>		
Pickup Delay	0.00	s	0.00 to 999.00
Operator 1			
Input A	<Unused = 0>		
Operator 2			
Input B	<Unused = 0>		
Operator 3			
Input C	<Unused = 0>		
Operator 4			
Input D	<Unused = 0>		
Operator 5			
Input E	<Unused = 0>		

Appendix C Hardware Description

The relay is a complete transformer protection relay package designed and manufactured with high quality features and recording components. The following information describes the main hardware components of the relay:

Main Processor Board (MPB)

The MPB has two processor sub-systems which control the operation of the entire relay: the DSP processor and the control processor. The DSP sub-system interfaces to the RAIB, the DIB and the OCB and manages the protection features of the relay. The control processor manages the user interface and system control features of the relay. Both subsystems operate independently of each other and will continue to function even if the other sub-system fails.

The MPB provides the following functionality:

- DSP processor subsystem which interfaces to the RAIB, the DIB and the OCB and manages the protection features of the relay, with:
    - The floating point DSP to provide fast capture and manipulation of data.
    - RAM and reprogrammable non-volatile Flash memory. Allows operation independent of the control processor and supports field software updates.
- A control processor subsystem which manages the user interface and system control features of the relay, with
    - RAM and reprogrammable non-volatile Flash memory. Allows operation independent of the DSP processor and supports field software upgrades.
    - Settings and recordings stored in non-volatile memory.
    - Runs a Real Time Operating System (RTOS).
    - Provides Ethernet ports and RS-232 ports for modem, SCADA, COM and USB interfaces.
- A time synchronism processor with automatic detection of modulated and unmodulated IRIG-B
- A high speed link is provided between the DSP and control processor subsystems.
- Sophisticated fault detection and “watchdog” recovery hardware
- The MPB also provides the power supply for the entire unit. The power supply operating range is 43 – 275 Vdc, 90 – 265 Vac, 50/60 Hz. This wide operating range provides easier installation by eliminating power supply ordering options

Digital Input Board (DIB)

This board provides 9 digital input channels. Inputs are optically isolated, externally wetted, and factory preset to the customer’s requested voltage level of 48,110/125 or 220/250 Vdc. This board interfaces to the MPB.

Rear Panel Comm Board (RPCB)

The RPCB provides the relay with two RS-232 ports (Ports 122 and 123, DB9F), IRIG-B time synchronization input (Port 121, male BNC), internal modem connection (Port 118, RJ-11) and two Ethernet ports (Ports 119 and 120, RJ-45 or 100BASE-FX MM 1300nm ST, depending upon order specification). The RPCB interfaces to the MPB. Port 119 is the exception in that it interfaces to the GFPCB where it shares an internal switch with the front panel LAN port. The switch then interfaces to the MPB.

Output Contact Board (LOCB)

The LOCB provides 14 normally open contact outputs for relaying, alarms and control. It also provides one normally closed output contact for relay inoperative indication. This board interfaces to the MPB.

Output Contact Board (LOCBH)

The LOCBH provides the following output contacts for relaying, alarms and control:

- One normally closed relay inoperative indicator normal output contact
- 6 user-defined normal output contacts with both normally open and normally closed terminals made available to the user
- 4 user-defined high current fast interrupting (HCFI) output contacts

The LOCBH interfaces to the MPB.

Digital Input/ Output Board (DIGIO)

The DIGIO provides 11 digital input channels. Inputs are optically isolated, externally wetted, and factory preset to the customer's requested voltage level of 48,110/125 or 220/250 Vdc. The DIGIO also provide 7 normally open contact outputs for relaying, alarms and control. This board interfaces to the MPB.

Relay AC Analog Sensor Boards (RASB)

Each relay has 3 RASBs. One RASB has 3 voltage transformer inputs and 3 current transformer inputs while the other two RASBs have 6 current transformer inputs. These boards provide 15 current and 3 voltage ac analog measurement inputs. The RASBs interface to the RAIB.

Relay AC Analog Input Board (RAIB)

The RAIB provides the analog to digital conversion of the 15 ac analog current inputs and the 3 ac analog voltage inputs. The sample rate is fixed at 96 samples/cycle. Each channel is simultaneously sampled using 16-bit analog to digital converters. The digitized data is sent to the MPB for processing and implementation of the protection algorithms.

Graphics Front Panel Comm Board (GFPCB)

The GFPCB provides the front panel USB and Ethernet ports, the front panel status LEDs and interfaces the MPB to the FPDB. The MPB controls the state of the LEDs.

Graphics Front Panel Display Board (GFPDB)

The GFPDB provides the 240x128 monochrome graphics front panel display and the keypad. The keypad is used to navigate the menus on the display to control relay operation by a local user.

Appendix D Event Messages

87 Trip on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC
87N-HV Trip	
87N-LV Trip	
87N-TV Trip	
51-HV Trip on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC
50-HV Trip on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC
51-LV Trip on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC
50-LV Trip on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC

51-TV Trip on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC
50-TV Trip on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC
51N-HV Trip on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG
50N-HV Trip on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG
51N-LV Trip on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG
50N-LV Trip on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG
51N-TV Trip on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG

50N-TV Trip on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG
67 Trip on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC
67N Trip on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG
24INV Trip	
24DEF-1 Trip	
24DEF-2 Trip	
59N Trip	
60 Alarm	
51-HV Alarm on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC
51-LV Alarm on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC

51-TV Alarm on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC
51N-HV Alarm on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG
51N-LV Alarm on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG
51N-TV Alarm on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG
67 Alarm on ABC	The possible phase information is • A • B • C • N • AB • BC • CA • ABC
67N Alarm on ABCG	The possible phase information is • AG • BG • CG • ABG • BCG • CAG • ABCG
24INV Alarm	
59N Alarm	
THD Exceeds Limit: Alrm	
Ambient (P1) - Range: Alrm	P1 - could be Over or Under
Top Oil (P1) - Range: Alrm	P1 - could be Over or Under

TOEWS: 15 min Alarm	
TOEWS: 30 min Alarm	
TOEWS: Trip	
49-1: Trip/Alarm	
49-2: Trip/Alarm	
49-3: Trip/Alarm	
49-4: Trip/Alarm	
49-5: Trip/Alarm	
49-6: Trip/Alarm	
49-7: Trip/Alarm	
49-8: Trip/Alarm	
49-9: Trip/Alarm	
49-10: Trip/Alarm	
49-11: Trip/Alarm	
49-12: Trip/Alarm	
81-1: Trip	
81-2: Trip	
81-3: Trip	
81-4: Trip	
50BF Initiated - HV	
50BF Initiated –LV	
50BF Initiated -TV	
50BF: Input1Trip1	
50BF: Input1 Trip2	
50BF: Input2Trip1	
50BF: Input2 Trip2	
50BF: Input3Trip1	
50BF: Input3 Trip2	
50BF: Input4Trip1	
50BF: Input4 Trip2	
50BF: Input5 Trip1	
50BF: Input5 Trip2	

59-1: Trip on ABC 59-2: Trip on ABC	The possible phase information is: • A • B • C • N • AB • BC • CA • ABC
27-1: Trip on ABC 27-2: Trip on ABC	The possible phase information is: • A • B • C • N • AB • BC • CA • ABC
I*I*t Alarm on ABC	The possible phase information is: • A • B • C • N • AB • BC • CA • ABC
ProLogic Name: PLn	ProLogic outputs names are user-assigned Where n = 1 to 24
External Input Name: EIn: High	External input names are user-assigned Where n = 1 to 20
External Input Name: EIn: Low	External input names are user-assigned Where n = 1 to 20
Output Contacts name: Out n: Open	Output contact names are user-assigned Where n= 1 to 21
Output Contacts name: Out n: Closed	Output contact names are user-assigned Where n= 1 to 21
Virtual Input 1:VI1 : Low	Virtual Input names are user-assigned Where n= 1 to 30
Virtual Input 1:VI1 : High	Virtual Input names are user-assigned Where n= 1 to 30
Self Check: DC Ch.n: Alarm	Continuous dc level on Ch. n, where n = 1 to 18.
Self Check: DC Alarm Reset	Continuous dc level, condition has reset.
Self Check: DC Ch.n: O/P Block	Continuous dc level on Ch. n, where n = 1 to 18.
Through Fault Peak Value	
Through Fault I2t Value	
New Setting Loaded	
Logic Setting Group Change	
User Setting Group Change	

Manual settings load request completed	Completion of user-initiated settings change
Unit recalibrated	
Unit restarted	
User logged in	

Appendix E Modbus RTU Communication Protocol

The SCADA port supports DNP3 and Modicon Modbus protocols. All metering values available through the terminal user interface are also available through the Modbus protocol. Additionally, the Modbus protocol supports the reading of unit time and time of the readings, and provides access to trip and alarm events, including fault location information.

A “Hold Readings” function is available to freeze all metering readings into a snapshot (see Force Single Coil function, address 0).

T-PRO 4000 Modbus Message Index List

Read Coil Status (Function Code 01)			
Channel	**Address**	**Value**	
Hold Readings	1	0: Readings not held	1: Readings held
Reserved	257	Reserved	Reserved
Output Contacts 1	513	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 2	514	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 3	515	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 4	516	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 5	517	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 6	518	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 7	519	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 8	520	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 9	521	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 10	522	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 11	523	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 12	524	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 13	525	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 14	526	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 15	527	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 16	528	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 17	529	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 18	530	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 19	531	0: Contact Open (inactive)	1: Contact Closed (active)
Output Contacts 20	532	0: Contact Open (inactive)	1: Contact Closed (active)

Output Contacts 21	533	0: Contact Open (inactive)	1: Contact Closed (active)
Differential (87) Trip	769	0: Off (inactive)	1: On (active)
Differential (87) Restraint	770	0: Off (inactive)	1: On (active)
87 Unrestrained	771	0: Off (inactive)	1: On (active)
D51HV Trip	772	0: Off (inactive)	1: On (active)
D51HV Alarm	773	0: Off (inactive)	1: On (active)
D50HV Trip	774	0: Off (inactive)	1: On (active)
D51LV Trip	775	0: Off (inactive)	1: On (active)
D51LV Alarm	776	0: Off (inactive)	1: On (active)
D50LV Trip	777	0: Off (inactive)	1: On (active)
D51TV Trip	778	0: Off (inactive)	1: On (active)
D51TV Alarm	779	0: Off (inactive)	1: On (active)
D50TV Trip	780	0: Off (inactive)	1: On (active)
D51N-HV Trip	781	0: Off (inactive)	1: On (active)
D51N-HV Alarm	782	0: Off (inactive)	1: On (active)
D50N-HV Trip	783	0: Off (inactive)	1: On (active)
D51N-LV Trip	784	0: Off (inactive)	1: On (active)
D51N-LV Alarm	785	0: Off (inactive)	1: On (active)
D50N-LV Trip	786	0: Off (inactive)	1: On (active)
D51N-TV Trip	787	0: Off (inactive)	1: On (active)
D51N-TV Alarm	788	0: Off (inactive)	1: On (active)
D50N-TV Trip	789	0: Off (inactive)	1: On (active)
Directional Overcurrent (67) Trip	790	0: Off (inactive)	1: On (active)
Directional Overcurrent (67) Alarm	791	0: Off (inactive)	1: On (active)
Volts/Hertz (24INV) Trip	792	0: Off (inactive)	1: On (active)
Volts/Hertz (24INV) Alarm	793	0: Off (inactive)	1: On (active)
Instantaneous Overexcitation (24DEF) trip	794	0: Off (inactive)	1: On (active)
D59N Trip	795	0: Off (inactive)	1: On (active)
D59N Alarm	796	0: Off (inactive)	1: On (active)
Loss of Potential (60) Alarm	797	0: Off (inactive)	1: On (active)
Total Harmonic Distortion Alarm	798	0: Off (inactive)	1: On (active)
Auxiliary device failure alarm	799	0: Off (inactive)	1: On (active)
Ambient out of range alarm	800	0: Off (inactive)	1: On (active)
Top oil out of range alarm	801	0: Off (inactive)	1: On (active)
D49-1 Trip/Alarm	802	0: Off (inactive)	1: On (active)
D49-2 Trip/Alarm	803	0: Off (inactive)	1: On (active)

D49-3 Trip/Alarm	804	0: Off (inactive)	1: On (active)
D49-4 Trip/Alarm	805	0: Off (inactive)	1: On (active)
D49-5 Trip/Alarm	806	0: Off (inactive)	1: On (active)
D49-6 Trip/Alarm	807	0: Off (inactive)	1: On (active)
D49-7 Trip/Alarm	808	0: Off (inactive)	1: On (active)
D49-8 Trip/Alarm	809	0: Off (inactive)	1: On (active)
D49-9 Trip/Alarm	810	0: Off (inactive)	1: On (active)
D49-10 Trip/Alarm	811	0: Off (inactive)	1: On (active)
D49-11 Trip/Alarm	812	0: Off (inactive)	1: On (active)
D49-12 Trip/Alarm	813	0: Off (inactive)	1: On (active)
D87N-HV Trip	814	0: Off (inactive)	1: On (active)
D87N-LV Trip	815	0: Off (inactive)	1: On (active)
D87N-TV Trip	816	0: Off (inactive)	1: On (active)
Toews15MinAlarm	817	0: Off (inactive)	1: On (active)
Toews30MinAlarm	818	0: Off (inactive)	1: On (active)
ToewsTrip	819	0: Off (inactive)	1: On (active)
ProLogic1	820	0: Off (inactive)	1: On (active)
ProLogic2	821	0: Off (inactive)	1: On (active)
ProLogic3	822	0: Off (inactive)	1: On (active)
ProLogic4	823	0: Off (inactive)	1: On (active)
ProLogic5	824	0: Off (inactive)	1: On (active)
ProLogic6	825	0: Off (inactive)	1: On (active)
ProLogic7	826	0: Off (inactive)	1: On (active)
ProLogic8	827	0: Off (inactive)	1: On (active)
ProLogic9	828	0: Off (inactive)	1: On (active)
ProLogic10	829	0: Off (inactive)	1: On (active)
81-1 Trip	830	0: Off (inactive)	1: On (active)
81-2 Trip	831	0: Off (inactive)	1: On (active)
81-3 Trip	832	0: Off (inactive)	1: On (active)
81-4 Trip	833	0: Off (inactive)	1: On (active)
27-1 Trip	834	0: Off (inactive)	1: On (active)
27-2 Trip	835	0: Off (inactive)	1: On (active)
I2t Alarm	836	0: Off (inactive)	1: On (active)
Instantaneous Overexcitation 24DEF-2 Trip	837	0: Off (inactive)	1: On (active)
D59-1 Trip	838	0: Off (inactive)	1: On (active)

D59-2Trip	839	0: Off (inactive)	1: On (active)
D50BF-Input1Trip1	840	0: Off (inactive)	1: On (active)
D50BF-Input1Trip2	841	0: Off (inactive)	1: On (active)
D50BF-Input2Trip1	842	0: Off (inactive)	1: On (active)
D50BF-Input2Trip2	843	0: Off (inactive)	1: On (active)
D50BF-Input3Trip1	844	0: Off (inactive)	1: On (active)
D50BF-Input3Trip2	845	0: Off (inactive)	1: On (active)
D50BF-Input4Trip1	846	0: Off (inactive)	1: On (active)
D50BF-Input4Trip2	847	0: Off (inactive)	1: On (active)
D50BF-Input5Trip1	848	0: Off (inactive)	1: On (active)
D50BF-Input5Trip2	849	0: Off (inactive)	1: On (active)
IRIG-B Signal Loss	850	0: Off (inactive)	1: On (active)
ProLogic11	851	0: Off (inactive)	1: On (active)
ProLogic12	852	0: Off (inactive)	1: On (active)
ProLogic13	853	0: Off (inactive)	1: On (active)
ProLogic14	854	0: Off (inactive)	1: On (active)
ProLogic15	855	0: Off (inactive)	1: On (active)
ProLogic16	856	0: Off (inactive)	1: On (active)
ProLogic17	857	0: Off (inactive)	1: On (active)
ProLogic18	858	0: Off (inactive)	1: On (active)
ProLogic19	859	0: Off (inactive)	1: On (active)
ProLogic20	860	0: Off (inactive)	1: On (active)
ProLogic21	861	0: Off (inactive)	1: On (active)
ProLogic22	862	0: Off (inactive)	1: On (active)
ProLogic23	863	0: Off (inactive)	1: On (active)
ProLogic24	864	0: Off (inactive)	1: On (active)
67N Trip	865	0: Off (inactive)	1: On (active)
67N Alarm	866	0: Off (inactive)	1: On (active)
67 Direction	867	0: Off (inactive)	1: On (active)
67N Direction	868	0: Off (inactive)	1: On (active)

Read Input Status (Function Code 02)			
Channel	**Address**	**Value**	
External Input 1	10001	0: Off (inactive)	1: On (active)
External Input 2	10002	0: Off (inactive)	1: On (active)
External Input 3	10003	0: Off (inactive)	1: On (active)
External Input 4	10004	0: Off (inactive)	1: On (active)
External Input 5	10005	0: Off (inactive)	1: On (active)
External Input 6	10006	0: Off (inactive)	1: On (active)
External Input 7	10007	0: Off (inactive)	1: On (active)
External Input 8	10008	0: Off (inactive)	1: On (active)
External Input 9	10009	0: Off (inactive)	1: On (active)
External Input 10	10010	0: Off (inactive)	1: On (active)
External Input 11	10011	0: Off (inactive)	1: On (active)
External Input 12	10012	0: Off (inactive)	1: On (active)
External Input 13	10013	0: Off (inactive)	1: On (active)
External Input 14	10014	0: Off (inactive)	1: On (active)
External Input 15	10015	0: Off (inactive)	1: On (active)
External Input 16	10016	0: Off (inactive)	1: On (active)
External Input 17	10017	0: Off (inactive)	1: On (active)
External Input 18	10018	0: Off (inactive)	1: On (active)
External Input 19	10019	0: Off (inactive)	1: On (active)
External Input 20	10020	0: Off (inactive)	1: On (active)
External Input 1 Change of state latch	10257	0: Off (inactive)	1: On (active)
External Input 2 Change of state latch	10258	0: Off (inactive)	1: On (active)
External Input 3 Change of state latch	10259	0: Off (inactive)	1: On (active)
External Input 4 Change of state latch	10260	0: Off (inactive)	1: On (active)
External Input 5 Change of state latch	10261	0: Off (inactive)	1: On (active)
External Input 6 Change of state latch	10262	0: Off (inactive)	1: On (active)
External Input 7 Change of state latch	10263	0: Off (inactive)	1: On (active)
External Input 8 Change of state latch	10264	0: Off (inactive)	1: On (active)
External Input 9 Change of state latch	10265	0: Off (inactive)	1: On (active)
External Input 10 Change of state latch	10266	0: Off (inactive)	1: On (active)
External Input 11 Change of state latch	10267	0: Off (inactive)	1: On (active)
External Input 12 Change of state latch	10268	0: Off (inactive)	1: On (active)

External Input 13 Change of state latch	10269	0: Off (inactive)	1: On (active)
External Input 14 Change of state latch	10270	0: Off (inactive)	1: On (active)
External Input 15 Change of state latch	10271	0: Off (inactive)	1: On (active)
External Input 16 Change of state latch	10272	0: Off (inactive)	1: On (active)
External Input 17 Change of state latch	10273	0: Off (inactive)	1: On (active)
External Input 18 Change of state latch	10274	0: Off (inactive)	1: On (active)
External Input 19 Change of state latch	10275	0: Off (inactive)	1: On (active)
External Input 20 Change of state latch	10276	0: Off (inactive)	1: On (active)
Virtual Input 1	10513	0: Off (inactive)	1: On (active)
Virtual Input 2	10514	0: Off (inactive)	1: On (active)
Virtual Input 3	10515	0: Off (inactive)	1: On (active)
Virtual Input 4	10516	0: Off (inactive)	1: On (active)
Virtual Input 5	10517	0: Off (inactive)	1: On (active)
Virtual Input 6	10518	0: Off (inactive)	1: On (active)
Virtual Input 7	10519	0: Off (inactive)	1: On (active)
Virtual Input 8	10520	0: Off (inactive)	1: On (active)
Virtual Input 9	10521	0: Off (inactive)	1: On (active)
Virtual Input 10	10522	0: Off (inactive)	1: On (active)
Virtual Input 11	10523	0: Off (inactive)	1: On (active)
Virtual Input 12	10524	0: Off (inactive)	1: On (active)
Virtual Input 13	10525	0: Off (inactive)	1: On (active)
Virtual Input 14	10526	0: Off (inactive)	1: On (active)
Virtual Input 15	10527	0: Off (inactive)	1: On (active)
Virtual Input 16	10528	0: Off (inactive)	1: On (active)
Virtual Input 17	10529	0: Off (inactive)	1: On (active)
Virtual Input 18	10530	0: Off (inactive)	1: On (active)
Virtual Input 19	10531	0: Off (inactive)	1: On (active)
Virtual Input 20	10532	0: Off (inactive)	1: On (active)
Virtual Input 21	10533	0: Off (inactive)	1: On (active)
Virtual Input 22	10534	0: Off (inactive)	1: On (active)
Virtual Input 23	10535	0: Off (inactive)	1: On (active)
Virtual Input 24	10536	0: Off (inactive)	1: On (active)
Virtual Input 25	10537	0: Off (inactive)	1: On (active)
Virtual Input 26	10538	0: Off (inactive)	1: On (active)
Virtual Input 27	10539	0: Off (inactive)	1: On (active)
Virtual Input 28	10540	0: Off (inactive)	1: On (active)

Virtual Input 29	10541	0: Off (inactive)	1: On (active)
Virtual Input 30	10542	0: Off (inactive)	1: On (active)

Read Holding Registers (Function Code 03)			
Channel	**Address**	**Units**	**Scale**
T-PRO Clock Time (UTC). Read all in same query to ensure consistent time reading data			
Milliseconds now * Millisecond information not supported.	40001	0	1
Seconds Now	40002	0-59	1
Minutes Now	40003	0-59	1
Hours Now	40004	0-23	1
Day of Year Now	40005	1-365 (up to 366 if leap year)	1
Years since 1900	40006	90-137	1
Sync'd to IRIG-B	40007	0: No 1: Yes	1
Time of Acquisition (UTC). Read all in same query to ensure consistent time reading data			
Milliseconds now * Millisecond information not supported.	40008	0	1
Seconds Now	40009	0-59	1
Minutes Now	40010	0-59	1
Hours Now	40011	0-23	1
Day of Year Now	40012	1-365 (up to 366 if leap year)	1
Years since 1900	40013	90-137	1
Sync'd to IRIG-B	40014	0: No 1: Yes	1
Offset of UTC of IED time	40015	2's complement half hours, North America is negative	1

Read Holding Registers (Function Code 03)			
Channel	**Address**	**Units**	**Scale**
Va Magnitude	40257	kV	10
Va Angle	40258	degrees	10
Vb Magnitude	40259	kV	10
Vb Angle	40260	degrees	10
Vc Magnitude	40261	kV	10
Vc Angle	40262	degrees	10
Voltage (V1)	40263	kV	10
I1 positive	40264	A	0.1
P	40265	MW	0.01
Q	40266	Mvar	0.01
I1a Magnitude	40267	A	0.1
I1a Angle	40268	Degrees	10
I1b Magnitude	40269	A	0.1
I1b Angle	40270	Degrees	10
I1c Magnitude	40271	A	0.1
I1c Angle	40272	Degrees	10
I2a Magnitude	40273	A	0.1
I2a Angle	40274	Degrees	10
I2b Magnitude	40275	A	0.1
I2b Angle	40276	Degrees	10
I2c Magnitude	40277	A	0.1
I2c Angle	40278	Degrees	10
I3a Magnitude	40279	A	0.1
I3a Angle	40280	Degrees	10
I3b Magnitude	40281	A	0.1
I3b Angle	40282	Degrees	10
I3c Magnitude	40283	A	0.1
I3c Angle	40284	Degrees	10
I4a Magnitude	40285	A	0.1
I4a Angle	40286	Degrees	10
I4b Magnitude	40287	A	0.1
I4b Angle	40288	Degrees	10

I4c Magnitude	40289	A	0.1
I4c Angle	40290	Degrees	10
I5a Magnitude	40291	A	0.1
I5a Angle	40292	Degrees	10
I5b Magnitude	40293	A	0.1
I5b Angle	40294	Degrees	10
I5c Magnitude	40295	A	0.1
I5c Angle	40296	Degrees	10
HVa Magnitude	40297	A	0.1
HVa Angle	40298	Degrees	10
HVb Magnitude	40299	A	0.1
HVb Angle	40300	Degrees	10
HVc Magnitude	40301	A	0.1
HVc Angle	40302	Degrees	10
LVa Magnitude	40303	A	0.1
LVa Angle	40304	Degrees	10
LVb Magnitude	40305	A	0.1
LVb Angle	40306	Degrees	10
LVc Magnitude	40307	A	0.1
LVc Angle	40308	Degrees	10
TVa Magnitude	40309	A	0.1
TVa Angle	40310	Degrees	10
TVb Magnitude	40311	A	0.1
TVb Angle	40312	Degrees	10
TVc Magnitude	40313	A	0.1
TVc Angle	40314	Degrees	10
Ia Operating	40315	Per Unit	1
Ib Operating	40316	Per Unit	1
Ic Operating	40317	Per Unit	1
Ia Restraint	40318	Per Unit	1
Ib Restraint	40319	Per Unit	1
Ic Restraint	40320	Per Unit	1
Frequency	40321	Hz	100
DC1	40322	mA	100
DC2	40323	mA	100
49 HV RMS Current in PU	40324	Per Unit	10

49 LV RMS Current in PU	40325	Per Unit	10
49 TV RMS Current in PU	40326	Per Unit	10
Toews: MinutesToTrip	40327	In minutes	1
Self check failure param.	40328	N/A	1
Ambient Temperature	40513	C	10
Top Oil Temperature	40514	C	10
Hot Spot Temperature	40515	C	10
Loss of Life	40516	Per Unit	100
51 Pickup Level	40517	Per Unit	100
THD	40518	%	100
Accumulated IA*IA*t	40519	KA*KA*S	10
Accumulated IB*IB*t	40520	KA*KA*S	10
Accumulated IC*IC*t	40521	KA*KA*S	10
Accumulated Through Fault Count	40522	N/A	1
S	40523	MVA	0.01
PF	40524	NA	100
Voltage (V0)	40525	kV	10
Voltage (V2)	40526	kV	10
I1 zero	40527	A	1
I1 negative	40528	A	1
I2 positive	40529	A	1
I2 zero	40530	A	1
I2 negative	40531	A	1
I3 positive	40532	A	1
I3 zero	40533	A	1
I3 negative	40534	A	1
I4 positive	40535	A	1
I4 zero	40536	A	1
I4 negative	40537	A	1
I5 positive	40538	A	1
I5 zero	40539	A	1
I5 negative	40540	A	1
HV 3I0 Magnitude	40541	A	1
HV 3I0 Angle	40542	degrees	10
LV 3I0 Magnitude	40543	A	1
LV 3I0 Angle	40544	degrees	10

TV 3I0 Magnitude	40545	A	1
TV 3I0 Angle	40546	degrees	10
HV REF IO	40547	A	1
LV REF IO	40548	A	1
TV REF IO	40549	A	1
HV REF IR	40550	A	1
LV REF IR	40551	A	1
TV REF IR	40552	A	1
HV IA 2nd Harmonic Magnitude	40553	%	100
HV IB 2nd Harmonic Magnitude	40554	%	100
HV IC 2nd Harmonic Magnitude	40555	%	100
LV IA 2nd Harmonic Magnitude	40556	%	100
LV IB 2nd Harmonic Magnitude	40557	%	100
LV IC 2nd Harmonic Magnitude	40558	%	100
TV IA 2nd Harmonic Magnitude	40559	%	100
TV IB 2nd Harmonic Magnitude	40560	%	100
TV IC 2nd Harmonic Magnitude	40561	%	100
I1a 2nd Harmonic Magnitude	40562	%	100
I1b 2nd Harmonic Magnitude	40563	%	100
I1c 2nd Harmonic Magnitude	40564	%	100
I2a 2nd Harmonic Magnitude	40565	%	100
I2b 2nd Harmonic Magnitude	40566	%	100
I2c 2nd Harmonic Magnitude	40567	%	100
I3a 2nd Harmonic Magnitude	40568	%	100
I3b 2nd Harmonic Magnitude	40569	%	100
I3c 2nd Harmonic Magnitude	40570	%	100
I4a 2nd Harmonic Magnitude	40571	%	100
I4b 2nd Harmonic Magnitude	40572	%	100
I4c 2nd Harmonic Magnitude	40573	%	100
I5a 2nd Harmonic Magnitude	40574	%	100
I5b 2nd Harmonic Magnitude	40575	%	100
I5c 2nd Harmonic Magnitude	40576	%	100
I1a 5th Harmonic Magnitude	40577	%	100
I1b 5th Harmonic Magnitude	40578	%	100
I1c 5th Harmonic Magnitude	40579	%	100
I2a 5th Harmonic Magnitude	40580	%	100

I2b 5th Harmonic Magnitude	40581	%	100
I2c 5th Harmonic Magnitude	40582	%	100
I3a 5th Harmonic Magnitude	40583	%	100
I3b 5th Harmonic Magnitude	40584	%	100
I3c 5th Harmonic Magnitude	40585	%	100
I4a 5th Harmonic Magnitude	40586	%	100
I4b 5th Harmonic Magnitude	40587	%	100
I4c 5th Harmonic Magnitude	40588	%	100
I5a 5th Harmonic Magnitude	40589	%	100
I5b 5th Harmonic Magnitude	40590	%	100
I5c 5th Harmonic Magnitude	40591	%	100
Pa	40592	MW	0.1
Pb	40593	MW	0.1
Pc	40594	MW	0.1
Qa	40595	Mvar	0.1
Qb	40596	Mvar	0.1
Qc	40597	Mvar	0.1
Sa	40598	MVA	0.1
Sb	40599	MVA	0.1
Sc	40600	MVA	0.1
PFa	40601	NA	100
PFb	40602	NA	100
PFc	40603	NA	100

Read Input Register (Function Code 04)
N input registers supported. Response from IED indicates “ILLEGAL FUCTION”

Force Single Coil (Function Code 05)			
Only the “hold readings” coil can be forced. When active, this coil locks al coil, input and holding register readings simultaneously at their present values. When inactive, coil, input and holding register values will read their most recently available state			
Channel	**Type**	**Address**	**Value**
Hold Readings	Read/Write	01	0000: Readings update normal (inactive) FF00: Hold readings (active)

Preset Single Registers (Function Code 06)			
Channel	**Address**	**Value**	**Scaled Up By**
Event Messages Control (See Below for details of use)			
Refresh event list	40769	No Data required	N/A
Acknowledge the current event and get the next event	40770	No Data required	N/A
Get the next event (without acknowledge)	40771	No Data required	N/A

Diagnostic Subfuctions (Function Code 08)	
Return Query Data (Subfuction 00)	This provides an echo of the submitted message
Restart Comm. Option (Subfunction 01)	This restarts the Modbus communication process.
Force Listen Only Mode (Subfunction 04)	No response is returned. IED enters “Listen Only” Mode. This mode can only be exited by the “Restart Comm. Option” command.

Report Slave ID (Funciton Code 17/0x11)			
A fixed response is returned by the IED, including system model, version and issue numbers.			
Channel	Type	Bytes	Values
Model Number	Read Only	0 and 1	0XfA0 = 4000 decimal
Version Number	Read Only	2 and 3	Version Number
Issue Number	Read Only	4 and 5	Issue Number

The T-PRO IED model number is 4000.

Version and issue will each be positive integers, say X and Y.

The T-PRO is defined as “Model 4000, Version X Issue Y”

Accessing T-PRO Event Information	
All T-PRO detector event messages displayed in the Event Log are available via Modbus. This includes fault location information. The following controls are available.	
Refresh Event List	(Function Code 6, address 40769): Fetches the latest events from the relay's event log and makes them available for Modbus access. The most recent event becomes the current event available for reading.
Acknowledge Current Event and Get Next Event	(Function Code 6, address 40770): Clears the current event from the read registers and places the next event into them. An acknowledged event is no longer available for reading.
Get Next Event	(Function Code 6, address 40771): Places the next event in the read registers without acknowledging the current event. The current event will reappear in the list when Refresh Event List is used.
Size of Current Event Message	(Function Code 3, address 40772): Indicates the number of 16 bit registers used to contain the current event. Event data is stored with 2 characters per register. A reading of zero indicates that there are no unacknowledged events available in the current set. (NB. The Refresh Event List function can be used to check for new events that have occurred since the last Refresh Event List.)
Read Event Message	(Function Code 3, addresses 40774– 40832): Contains the current message. Two.ASCII characters are packed into each 16 bit register. All unused registers in the set are set to 0.

Appendix F DNP3 Device Profile

Device Properties

This document shows the device capabilities and the current value of each parameter for the default unit configuration as defined in the default configuration file.

1.1 Device Identification	Capabilities	Current Value	If configurable, list methods
1.1.1 Device Function:	○ Master ● Outstation	○ Master ● Outstation	
1.1.2 Vendor Name:		ERLPhase Power Technologies	
1.1.3 Device Name:		T-PRO 4000	
1.1.4 Device manufacturer's hardware version string:		NA	
1.1.5 Device manufacturer's software version string:		NA	
1.1.6 Device Profile Document Version Number:		V1.1, Dec 12, 2014	
1.1.7 DNP Levels Supported for:	Masters Only Requests Responses ☐ ☐ None ☐ ☐ Level 1 ☐ ☐ Level 2 ☐ ☐ Level 3 Outstations Only Requests and Responses ☐ None ☐ Level 1 ☒ Level 2 ☐ Level 3		
1.1.8 Supported Function Blocks:	☐ Self-Address Reservation ☐ Object 0 - attribute objects ☐ Data Sets ☐ File Transfer ☐ Virtual Terminal ☐ Mapping to IEC 61850 Object Models defined in a DNP3 XML file		

1.1 Device Identification	Capabilities	Current Value	If configurable, list methods
1.1.9 Notable Additions:	• Start-stop (qualifier codes 0x00 and 0x01), limited quantity (qualifier codes 0x07 and 0x08) and indices (qualifier codes 0x17 and 0x28) for Binary Inputs, Binary Outputs and Analog Inputs (object groups 1, 10 and 30) • 32-bit and 16-bit Analog Inputs with and without flag (variations 1, 2, 3 and 4) • Analog Input events with time (variations 3 and 4) • Fault Location information as analog readings • Event Log messages as Object groups 110 and 111		
1.1.10 Methods to set Configurable Parameters:	☐ XML - Loaded via DNP3 File Transfer ☐ XML - Loaded via other transport mechanism ☐ Terminal - ASCII Terminal Command Line ☒ Software - Vendor software named T-PRO Offliner ☐ Proprietary file loaded via DNP3 file transfer ☐ Proprietary file loaded via other transport mechanism ☐ Direct - Keypad on device front panel ☐ Factory - Specified when device is ordered ☐ Protocol - Set via DNP3 (e.g. assign class) ☐ Other - explain _____		
1.1.11 DNP3 XML files available On-Line:	RdWrFilename Description of Contents ☐ dnpDP.xml Complete Device Profile ☐ dnpDPcap.xml Device Profile Capabilities ☐ dnpDPcfg.xml Device Profile config. values ☐ ☐ _____*.xml _____ *The Complete Device Profile Document contains the capabilities, Current Value, and configurable methods columns. *The Device Profile Capabilities contains only the capabilities and configurable methods columns. *The Device Profile Config. Values contains only the Current Value column.	Not supported	
1.1.12 External DNP3 XML files available Off-line:	Rd WrFilenameDescription of Contents ☐ ☐ dnpDP.xml Complete Device Profile ☐ ☐ dnpDPcap.xml Device Profile Capabilities ☐ ☐ dnpDPcfg.xml Device Profile config. values ☐ ☐ _____*.xml _____ *The Complete Device Profile Document contains the capabilities, Current Value, and configurable methods columns. *The Device Profile Capabilities contains only the capabilities and configurable methods columns. *The Device Profile Config. Values contains only the Current Value column.	Not supported	
1.1.13 Connections Supported:	☒ Serial (complete section 1.2) ☒ IP Networking (complete section 1.3) ☐ Other, explain _____		

1.2 Serial Connections		Capabilities	Current Value	If configurable, list methods
1.2.1	Port Name	Port 122		
1.2.2	Serial Connection Parameters:	☐ Asynchronous - 8 Data Bits, 1 Start Bit, 1 Stop Bit, No Parity ☒ Other, explain - Asynchronous with selectable parity	Not configured for DNP	T-PRO Offliner
1.2.3	Baud Rate:	☐ Fixed at _____ ☐ Configurable, range _____ to _____ ☒ Configurable, selectable from 300, 1200, 2400, 9600, 19200, 38400 and 57600 ☐ Configurable, other, describe_____	Not configured for DNP	T-PRO Offliner
1.2.4	Hardware Flow Control (Handshaking): Describe hardware signaling requirements of the interface. Where a transmitter or receiver is inhibited until a given control signal is asserted, it is considered to require that signal prior to sending or receiving characters. Where a signal is asserted prior to transmitting, that signal will be maintained active until after the end of transmission. Where a signal is asserted to enable reception, any data sent to the device when the signal is not active could be discarded.	☐ None **RS-232 / V.24 / V.28 Options:** Before Tx, Asserts: ☐ RTS ☐ DTR Before Rx, Asserts: ☐ RTS ☐ DTR Always Asserts: ☒ RTS ☒ DTR Before Tx, Requires: Asserted Deasserted ☐ ☐ CTS ☐ ☐ DCD ☐ ☐ DSR ☐ ☐ RI ☐ Rx Inactive Before Rx, Requires: Asserted Deasserted ☐ ☐ CTS ☐ ☐ DCD ☐ ☐ DSR ☐ ☐ RI Always Ignores: ☒ CTS ☒ DCD ☒ DSR ☒ RI ☐ Other, explain _____ **RS-422 / V.11 Options:** ☐ Requires Indication before Rx ☐ Asserts Control before Tx ☐ Other, explain _____ **RS-485 Options:** ☐ Requires Rx inactive before Tx ☐ Other, explain _____		
1.2.5	Interval to Request Link Status:	☒ Not Supported ☐ Fixed at_____ seconds ☐ Configurable, range _____ to _____ seconds ☐ Configurable, selectable from __,__,__ seconds ☐ Configurable, other, describe_____		
1.2.6	Supports DNP3 Collision Avoidance:	☒ No ☐ Yes, explain _____		

1.2 Serial Connections	Capabilities	Current Value	If configurable, list methods
1.2.7 Receiver Inter-character Timeout:	☒ Not checked ☐ No gap permitted ☐ Fixed at _____ bit times ☐ Fixed at _____ ms ☐ Configurable, range ____ to ____ bit times ☐ Configurable, range ____ to ____ ms ☐ Configurable, Selectable from __,__,__bit times ☐ Configurable, Selectable from ___, ___, ___ ms ☐ Configurable, other, describe_____ ☐ Variable, explain ____		
1.2.8 Inter-character gaps in transmission:	☒ None (always transmits with no inter-character gap) ☐ Maximum _____ bit times ☐ Maximum _____ ms		

1.3 IP Networking	Capabilities	Current Value	If configurable, list methods
1.3.1 Port Name	Port 119 and Port 120		
1.3.2 Type of End Point:	☐ TCP Initiating (Master Only) ☒ TCP Listening (Outstation Only) ☐ TCP Dual (required for Masters) ☒ UDP Datagram (required)	Not configured for DNP	T-PRO Offliner
1.3.3 IP Address of this Device:		192.168.100.101	T-PRO Maintenance utilities
1.3.4 Subnet Mask:		Not set	T-PRO Maintenance utilities
1.3.5 Gateway IP Address:		Not set	T-PRO Maintenance utilities
1.3.6 Accepts TCP Connections or UDP Datagrams from:	☒ Allows all (show as *.*.*.* in 1.3.7) ☒ Limits based on an IP address ☒ Limits based on list of IP addresses ☐ Limits based on a wildcard IP address ☐ Limits based on list of wildcard IP addresses ☐ Other validation, explain_____	Limits based on an IP address	T-PRO Offliner
1.3.7 IP Address(es) from which TCP Connections or UDP Datagrams are accepted:		192.168.1.1	T-PRO Offliner
1.3.8 TCP Listen Port Number:	☐ Not Applicable (Master w/o dual end point) ☐ Fixed at 20,000 ☒ Configurable, range 1025 to 32737 ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____	20,000	T-PRO Offliner
1.3.9 TCP Listen Port Number of remote device:	☒ Not Applicable (Outstation w/o dual end point) ☐ Fixed at 20,000 ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____	NA	
1.3.10 TCP Keep-alive timer:	☐ Fixed at _____ms ☒ Configurable, range 5 to 3,600 s ☐ Configurable, selectable from ___,___,___ms ☐ Configurable, other, describe_____	Disabled	T-PRO Offliner
1.3.11 Local UDP port:	☐ Fixed at 20,000 ☒ Configurable, range 1025 to 32737 ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____ ☐ Let system choose (Master only)	20,000	T-PRO Offliner
1.3.12 Destination UDP port for DNP3 Requests (Master Only):		NA	

1.3 IP Networking	Capabilities	Current Value	If configurable, list methods
1.3.13 Destination UDP port for initial unsolicited null responses (UDP only Outstations):	T None ☐ Fixed at 20,000 ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____ ☐ Use source port number	NA	
1.3.14 Destination UDP port for responses::	☐ None ☐ Fixed at 20,000 ☒ Configurable, range 1025 to 32737 ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____ ☐ Use source port number	20,000	T-PRO Offliner
1.3.15 Multiple master connections (Outstations Only):	☒ Supports multiple masters (Outstations only) If supported, the following methods may be used: ☒ Method 1 (based on IP address) - required ☒ Method 2 (based on IP port number) - recommended ☒ Method 3 (browsing for static data) - optional	Method 1 (based on IP address)	T-PRO Offliner
1.3.16 Time synchronization support:	☐ DNP3 LAN procedure (function code 24) ☐ DNP3 Write Time (not recommended over LAN) ☐ Other, explain _____ ☒ Not Supported		

1.4 Link Layer		Current Value	If configurable, list methods
1.4.1 Data Link Address:	☐ Fixed at_____ ☒ Configurable, range 1 to 65519 ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____	1	T-PRO Offliner
1.4.2 DNP3 Source Address Validation:	☒ Never ☐ Always, one address allowed (shown in 1.4.3) ☐ Always, any one of multiple addresses allowed ☐ (each selectable as shown in 1.4.3) ☐ Sometimes, explain_____		
1.4.3 DNP3 Source Address(es) expected when Validation is Enabled:	☐ Configurable to any 16 bit DNP Data Link Address value ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____	NA	
1.4.4 Self Address Support using address 0xFFFC:	☐ Yes (only allowed if configurable) ☒ No	NA	
1.4.5 Sends Confirmed User Data Frames:	☐ Always ☐ Sometimes, explain _____ ☐ Never ☒ Configurable, either always or never		T-PRO Offliner (to disable, set Data Link Time-out to 0)
1.4.6 Data Link Layer Confirmation Timeout:	☐ None ☐ Fixed at __ ms ☒ Configurable, range 0 to 2,000 ms ☐ Configurable, selectable from_____ms ☐ Configurable, other, describe_____ ☐ Variable, explain _____	500	
1.4.7 Maximum Data Link Retries:	☐ Never Retries ☒ Fixed at 3 ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____	3	
1.4.8 Maximum number of octets Transmitted in a Data Link Frame:	☒ Fixed at 292 ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____	292	
1.4.9 Maximum number of octets that can be Received in a Data Link Frame:	☒ Fixed at 292 ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____	292	

1.5 Application Layer		Current Value	If configurable, list methods
1.5.1 Maximum number of octets Transmitted in an Application Layer Fragment other than File Transfer:	☒ Fixed at 2048 ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____	2048	
1.5.2 Maximum number of octets Transmitted in an Application Layer Fragment containing File Transfer:	☐ Fixed at _____ ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____	NA	
1.5.3 Maximum number of octets that can be Received in an Application Layer Fragment:	☒ Fixed at 2048 ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____	2048	
1.5.4 Timeout waiting for Complete Application Layer Fragment:	☐ None ☒ Fixed at 2,000 ms ☐ Configurable, range _____ to _____ms ☐ Configurable, selectable from ___,___,___ms ☐ Configurable, other, describe_____ ☐ Variable, explain _____	2,000 ms	
1.5.5 Maximum number of objects allowed in a single control request for CROB (group 12):	☒ Fixed at 16 ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____ ☐ Variable, explain _____	16	
1.5.6 Maximum number of objects allowed in a single control request for Analog Outputs (group 41):	☐ Fixed at _ ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____ ☐ Variable, explain _____	Analog Outputs not supported	
1.5.7 Maximum number of objects allowed in a single control request for Data Sets (groups 85,86,87):	☐ Fixed at __ ☐ Configurable, range _____ to _____ ☐ Configurable, selectable from ____,____,____ ☐ Configurable, other, describe_____ ☐ Variable, explain _____	Data Sets not supported	
1.5.8 Supports mixing object groups (AOBs, CROBs and Data Sets) in the same control request:	☐ Not applicable - controls are not supported ☐ Yes ☒ No	Analog Outputs not supported	

1.6 Fill Out The Following Items For Outstations Only		**Current Value**	**If configurable, list methods**
1.6.1 Timeout waiting for Application Confirm of solicited response message:	☐ None ☒ Fixed at 5,000 ms ☐ Configurable, range _____ to _____ms ☐ Configurable, selectable from ___,___,___ms ☐ Configurable, other, describe_____ ☐ Variable, explain _____	5,000 ms	
1.6.2 How often is time synchronization required from the master?	☒ Never needs time ☐ Within _____ seconds after IIN1.4 is set ☐ Periodically every _____ seconds		
1.6.3 Device Trouble Bit IIN1.6:	☐ Never used ☒ Reason for setting: Unable to access requested data or execute CROB, assuming a valid request has been received		
1.6.4 File Handle Timeout:	☒ Not applicable, files not supported ☐ Fixed at_____ ms ☐ Configurable, range _____ to _____ms ☐ Configurable, selectable from ___,___,___ms ☐ Configurable, other, describe_____ ☐ Variable, explain _____		
1.6.5 Event Buffer Overflow Behaviour:	☐ Discard the oldest event ☒ Discard the newest event ☐ Other, explain _____		
1.6.6 Event Buffer Organization:	• Single buffer for the Object Groups 2 and 32, size 200. • Separate buffer for the Object Group 111, size 100. • Separate buffer for the Fault Locator events, size 100.		
1.6.7 Sends Multi-Fragment Responses:	☒ Yes ☐ No		
1.6.8 DNP Command Settings preserved through a device reset:	☐ Assign Class ☐ Analog Deadbands ☐ Data Set Prototypes ☐ Data Set Descriptors	Not supported	

1.7 Outstation Unsolicited Response Support		Current Value	If configurable, list methods
1.7.1 Supports Unsolicited Reporting:	☒ Not Supported ☐ Configurable, selectable from On and Off	NA	

1.8 Outstation Performance		Current Value	If configurable, list methods
1.8.1 Maximum Time Base Drift (milliseconds per minute):		NA, not synchronized by DNP	
1.8.2 When does outstation set IIN1.4?	☒ Never ☐ Asserted at startup until first Time Synchronization request received ☐ Periodically, range ____to____ seconds ☐ Periodically, selectable from ____,____,___ seconds ☐ Range ____to____ seconds after last time sync ☐ Selectable from___,___,___seconds after last time sync ☐ When time error may have drifted by range ____to____ ms ☐ When time error may have drifted by selectable from ____,____,___	NA	
1.8.3 Maximum Internal Time Reference Error when set via DNP (ms):		NA	
1.8.4 Maximum Delay Measurement error (ms):		NA	
1.8.5 Maximum Response time (ms):		100 ms (for the case all supported points mapped to the DNP point lists)	T-PRO Offliner
1.8.6 Maximum time from start-up to IIN 1.4 assertion (ms):		NA	
1.8.7 Maximum Event Time-tag error for local Binary and Double-bit I/O (ms):		• 0.1736 ms for 60Hz systems • 0.2083 ms for 50 Hz systems	
1.8.8 Maximum Event Time-tag error for local I/O other than Binary and Double-bit data types (ms):		• 0.1736 ms for 60Hz systems • 0.2083 ms for 50 Hz systems	

Capabilities and Current Settings for Device Database

The following tables identify the capabilities and current settings for each DNP3 data type. Each data type also provides a table defining the data points available in the device, default point lists configuration and a description of how this information can be obtained in case of customized point configuration.

2.1 Single-Bit Binary Inputs		Capabilities	Current Value	If configurable, list methods
2.1.1	Static Variation reported when variation 0 requested:	☒ Variation 1 - Single-bit Packed format ☐ Variation 2 - Single-bit with flag ☐ Based on point Index (add column to table below)		
2.1.2	Event Variation reported when variation 0 requested:	☐ Variation 1 - without time ☒ Variation 2 - with absolute time ☐ Variation 3 - with relative time ☐ Based on point Index (add column to table below)		
2.1.3	Event reporting mode:	☐ Only most recent ☒ All events		
2.1.4	Binary Inputs included in Class 0 response:	☒ Always ☐ Never ☐ Only if point is assigned to Class 1, 2, or 3 ☐ Based on point Index (add column to table below)		T-PRO Offliner
2.1.5	Definition of Binary Input Point List:	☐ Fixed, list shown in table below ☒ Configurable ☐ Other, explain_____	Complete list is shown in the table below; points excluded from the default configuration are marked with '*'	T-PRO Offliner

Notes	
	1. Binary Inputs are scanned with 1 ms resolution. 2. Binary Input data points are user selectable; the data points available in the device for any given Binary Input point selection can be obtained through the T-PRO Offliner software (see SCADA Setting Summary).

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Name for State when value is 0	Name for State when value is 1	Description
0	External Input 1	1	Inactive	Active	
1	External Input 2	1	Inactive	Active	
2	External Input 3	1	Inactive	Active	
3	External Input 4	1	Inactive	Active	
4	External Input 5	1	Inactive	Active	
5	External Input 6	1	Inactive	Active	
6	External Input 7	1	Inactive	Active	
7	External Input 8	1	Inactive	Active	
8	External Input 9	1	Inactive	Active	
9	Virtual Input 1	1	Inactive	Active	
10	Virtual Input 2	1	Inactive	Active	
11	Virtual Input 3	1	Inactive	Active	
12	Virtual Input 4	1	Inactive	Active	
13	Virtual Input 5	1	Inactive	Active	
14	Virtual Input 6	1	Inactive	Active	
15	Virtual Input 7	1	Inactive	Active	
16	Virtual Input 8	1	Inactive	Active	
17	Virtual Input 9	1	Inactive	Active	
18	Virtual Input 10	1	Inactive	Active	
19	Virtual Input 11	1	Inactive	Active	
20	Virtual Input 12	1	Inactive	Active	
21	Virtual Input 13	1	Inactive	Active	
22	Virtual Input 14	1	Inactive	Active	
23	Virtual Input 15	1	Inactive	Active	
24	Virtual Input 16	1	Inactive	Active	
25	Virtual Input 17	1	Inactive	Active	
26	Virtual Input 18	1	Inactive	Active	
27	Virtual Input 19	1	Inactive	Active	
28	Virtual Input 20	1	Inactive	Active	
29	Virtual Input 21	1	Inactive	Active	
30	Virtual Input 22	1	Inactive	Active	
31	Virtual Input 23	1	Inactive	Active	

32	Virtual Input 24	1	Inactive	Active	
33	Virtual Input 25	1	Inactive	Active	
34	Virtual Input 26	1	Inactive	Active	
35	Virtual Input 27	1	Inactive	Active	
36	Virtual Input 28	1	Inactive	Active	
37	Virtual Input 29	1	Inactive	Active	
38	Virtual Input 30	1	Inactive	Active	
39	87 Trip	1	Inactive	Active	
40	87 Restrain	1	Inactive	Active	
41	87 Unrestrained	1	Inactive	Active	
42	51-HV Trip	1	Inactive	Active	
43	51-HV Alarm	1	Inactive	Active	
44	50-HV Trip	1	Inactive	Active	
45	51-LV Trip	1	Inactive	Active	
46	51-LV Alarm	1	Inactive	Active	
47	50-LV Trip	1	Inactive	Active	
48	51-TV Trip	1	Inactive	Active	
49	51-TV Alarm	1	Inactive	Active	
50	50-TV Trip	1	Inactive	Active	
51	51N-HV Trip	1	Inactive	Active	
52	51N-HV Alarm	1	Inactive	Active	
53	50N-HV Trip	1	Inactive	Active	
54	51N-LV Trip	1	Inactive	Active	
55	51N-LV Alarm	1	Inactive	Active	
56	50N-LV Trip	1	Inactive	Active	
57	51N-TV Trip	1	Inactive	Active	
58	51N-TV Alarm	1	Inactive	Active	
59	50N-TV Trip	1	Inactive	Active	
60	67 Trip	1	Inactive	Active	
61	67 Alarm	1	Inactive	Active	
62	24INV Trip	1	Inactive	Active	
63	24INV Alarm	1	Inactive	Active	
64	24DEF-1 Trip	1	Inactive	Active	
65	59N Trip	1	Inactive	Active	
66	59N Alarm	1	Inactive	Active	
67	60 Alarm	1	Inactive	Active	

68	THD Alarm	1	Inactive	Active	
69	Self Check Fail	1	Inactive	Active	
70	Ambient Temperature Alarm	1	Inactive	Active	
71	Top Oil Temperature Alarm	1	Inactive	Active	
72	49-1 Operates	1	Inactive	Active	
73	49-2 Operates	1	Inactive	Active	
74	49-3 Operates	1	Inactive	Active	
75	49-4 Operates	1	Inactive	Active	
76	49-5 Operates	1	Inactive	Active	
77	49-6 Operates	1	Inactive	Active	
78	49-7 Operates	1	Inactive	Active	
79	49-8 Operates	1	Inactive	Active	
80	49-9 Operates	1	Inactive	Active	
81	49-10 Operates	1	Inactive	Active	
82	49-11 Operates	1	Inactive	Active	
83	49-12 Operates	1	Inactive	Active	
84	87N-HV Trip	1	Inactive	Active	
85	87N-LV Trip	1	Inactive	Active	
86	87N-TV Trip	1	Inactive	Active	
87	TOEWS 15 Minute Alarm	1	Inactive	Active	
88	TOEWS 30 Minute Alarm	1	Inactive	Active	
89	TOEWS Trip	1	Inactive	Active	
90	ProLogic1	1	Inactive	Active	
91	ProLogic2	1	Inactive	Active	
92	ProLogic3	1	Inactive	Active	
93	ProLogic4	1	Inactive	Active	
94	ProLogic5	1	Inactive	Active	
95	ProLogic6	1	Inactive	Active	
96	ProLogic7	1	Inactive	Active	
97	ProLogic8	1	Inactive	Active	
98	ProLogic9	1	Inactive	Active	
99	ProLogic10	1	Inactive	Active	
100	81-1 Trip	1	Inactive	Active	OR of 81-1 OF, UF and RC Trips
101	81-2 Trip	1	Inactive	Active	OR of 81-2 OF, UF and RC Trips

102	81-3 Trip	1	Inactive	Active	OR of 81-3 OF, UF and RC Trips
103	81-4 Trip	1	Inactive	Active	OR of 81-4 OF, UF and RC Trips
104	27-1 Trip	1	Inactive	Active	
105	27-2 Trip	1	Inactive	Active	
106	I*I*t Alarm	1	Inactive	Active	
107	24DEF -2 Trip	1	Inactive	Active	
108	59-1 Trip	1	Inactive	Active	
109	59-2 Trip	1	Inactive	Active	
110	50BF-Input1-Trip1	1	Inactive	Active	
111	50BF-Input1-Trip2	1	Inactive	Active	
112	50BF-Input2-Trip1	1	Inactive	Active	
113	50BF-Input2-Trip2	1	Inactive	Active	
114	50BF-Input3-Trip1	1	Inactive	Active	
115	50BF-Input3-Trip2	1	Inactive	Active	
116	50BF-Input4-Trip1	1	Inactive	Active	
117	50BF-Input4-Trip2	1	Inactive	Active	
118	50BF-Input5-Trip1	1	Inactive	Active	
119	50BF-Input5-Trip2	1	Inactive	Active	
120	50BF Initiated-HV	1	Inactive	Active	
121	50BF Initiated -LV	1	Inactive	Active	
122	50BF Initiated -TV	1	Inactive	Active	
123	IRIG-B Signal Loss	1	Inactive	Active	
124*	Output contact 1	1	Open	Closed	
125*	Output contact 2	1	Open	Closed	
126*	Output contact 3	1	Open	Closed	
127*	Output contact 4	1	Open	Closed	
128*	Output contact 5	1	Open	Closed	
129*	Output contact 6	1	Open	Closed	
130*	Output contact 7	1	Open	Closed	
131*	Output contact 8	1	Open	Closed	
132*	Output contact 9	1	Open	Closed	
133*	Output contact 10	1	Open	Closed	
134*	Output contact 11	1	Open	Closed	
135*	Output contact 12	1	Open	Closed	

136*	Output contact 13	1	Open	Closed	
137*	Output contact 14	1	Open	Closed	
138*	Output contact 15	1	Open	Closed	
139*	Output contact 16	1	Open	Closed	
140*	Output contact 17	1	Open	Closed	
141*	Output contact 18	1	Open	Closed	
142*	Output contact 19	1	Open	Closed	
143*	Output contact 20	1	Open	Closed	
144*	Output contact 21	1	Open	Closed	
145*	External Input 10	1	Inactive	Active	
146*	External Input 11	1	Inactive	Active	
147*	External Input 12	1	Inactive	Active	
148*	External Input 13	1	Inactive	Active	
149*	External Input 14	1	Inactive	Active	
150*	External Input 15	1	Inactive	Active	
151*	External Input 16	1	Inactive	Active	
152*	External Input 17	1	Inactive	Active	
153*	External Input 18	1	Inactive	Active	
154*	External Input 19	1	Inactive	Active	
155*	External Input 20	1	Inactive	Active	
156*	87 Trip A	1	Inactive	Active	
157*	87 Trip B	1	Inactive	Active	
158*	87 Trip C	1	Inactive	Active	
159*	27-1 Trip A	1	Inactive	Active	
160*	27-1 Trip B	1	Inactive	Active	
161*	27-1 Trip C	1	Inactive	Active	
162*	27-2 Trip A	1	Inactive	Active	
163*	27-2 Trip B	1	Inactive	Active	
164*	27-2 Trip C	1	Inactive	Active	
165*	59-1 Trip A	1	Inactive	Active	
166*	59-1 Trip B	1	Inactive	Active	
167*	59-1 Trip C	1	Inactive	Active	
168*	59-2 Trip A	1	Inactive	Active	
169*	59-2 Trip B	1	Inactive	Active	
170*	59-2 Trip C	1	Inactive	Active	
171	ProLogic 11	1	Inactive	Active	

172	ProLogic 12	1	Inactive	Active	
173	ProLogic 13	1	Inactive	Active	
174	ProLogic 14	1	Inactive	Active	
175	ProLogic 15	1	Inactive	Active	
176	ProLogic 16	1	Inactive	Active	
177	ProLogic 17	1	Inactive	Active	
178	ProLogic 18	1	Inactive	Active	
179	ProLogic 19	1	Inactive	Active	
180	ProLogic 20	1	Inactive	Active	
181	ProLogic 21	1	Inactive	Active	
182	ProLogic 22	1	Inactive	Active	
183	ProLogic 23	1	Inactive	Active	
184	ProLogic 24	1	Inactive	Active	
185	67N Trip	1	Inactive	Active	
186	67N Alarm	1	Inactive	Active	
187	67 Direction	1	Inactive	Active	
188	67N Direction	1	Inactive	Active	
189*	81-1 O/F Trip	1	Inactive	Active	
190*	81-1 U/F Trip	1	Inactive	Active	
191*	81-1 ROC Trip	1	Inactive	Active	
192*	81-2 O/F Trip	1	Inactive	Active	
193*	81-2 U/F Trip	1	Inactive	Active	
194*	81-2 ROC Trip	1	Inactive	Active	
195*	81-3 O/F Trip	1	Inactive	Active	
196*	81-3 U/F Trip	1	Inactive	Active	
197*	81-3 ROC Trip	1	Inactive	Active	
198*	81-4 O/F Trip	1	Inactive	Active	
199*	81-4 U/F Trip	1	Inactive	Active	
200*	81-4 ROC Trip	1	Inactive	Active	

2.2 Binary Output Status And Control Relay Output Block	Capabilities	Current Value	If configurable, list methods
2.2.1 Minimum pulse time allowed with Trip, Close, and Pulse On commands:	☒ Fixed at 0.000 ms (hardware may limit this further) ☐ Based on point Index (add column to table below)		
2.2.2 Maximum pulse time allowed with Trip, Close, and Pulse On commands:	☒ Fixed at 0.000 ms (hardware may limit this further) ☐ Based on point Index (add column to table below)		
2.2.3 Binary Output Status included in Class 0 response:	☒ Always ☐ Never ☐ Only if point is assigned to Class 1, 2, or 3 ☐ Based on point Index (add column to table below)		
2.2.4 Reports Output Command Event Objects:	☒ Never ☐ Only upon a successful Control ☐ Upon all control attempts	Not supported	
2.2.5 Event Variation reported when variation 0 requested:	☐ Variation 1 - without time ☐ Variation 2 - with absolute time ☐ Based on point Index (add column to table below)	Not supported	T-PRO Offliner (See Note 2 below)
2.2.6 Command Event Variation reported when variation 0 requested:	☐ Variation 1 - without time ☐ Variation 2 - with absolute time ☐ Based on point Index (add column to table below)	Not supported	T-PRO Offliner (See Note 2 below)
2.2.7 Event reporting mode:	☐ Only most recent ☐ All events	Not supported	T-PRO Offliner (See Note 2 below)
2.2.8 Command Event reporting mode:	☐ Only most recent ☐ All events	Not supported	
2.2.9 Maximum Time between Select and Operate:	☐ Not Applicable ☒ Fixed at 10 seconds ☐ Configurable, range _____ to _____ seconds ☐ Configurable, selectable from___,___,___seconds ☐ Configurable, other, describe_____ ☐ Variable, explain _____ ☐ Based on point Index (add column to table below)	10 s	
2.2.10 Definition of Binary Output Status/Control relay output block (CROB) Point List:	☐ Fixed, list shown in table below ☒ Configurable ☐ Other, explain_____	Complete list is shown in the table below; points excluded from the default configuration are marked with '*'	T-PRO Offliner

NOTES

1. Binary Outputs are scanned with 500 ms resolution.

2. Events are not supported for Binary Outputs (group 10), but most of Binary Output points can be mapped to Binary Inputs (group 2) with full Event and Class Data support. See T-PRO Offliner/DNP Configuration/Point Map screen for complete point lists and configuration options.

3. Virtual Inputs (default Binary Output points 14 - 43) can be used to control relay output contacts. See T-PRO Offliner/Setting Group X/Output Matrix screen for configuration options.

4. Binary Output data points are user selectable; the data points available in the device for any given Binary Output point selection can be obtained through the T-PRO Offliner software (see SCADA Setting Summary).

Point Index	Name	Supported Control Operations											Name for State when value is 0	Name for State when value is 1	Default Class Assigned to Events (1, 2, 3 or none)		Description
		Select/Operate	Direct Operate	Direct Operate - No Ack	Pulse On / NUL	Pulse Off	Latch On / NUL	Latch Off / NUL	Trip	Close	Count > 1	Cancel Currently Running Operation			Change	Command	
0	Output contact 1	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
1	Output contact 2	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
2	Output contact 3	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
3	Output contact 4	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
4	Output contact 5	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
5	Output contact 6	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
6	Output contact 7	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
7	Output contact 8	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
8	Output contact 9	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
9	Output contact 10	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
10	Output contact 11	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
11	Output contact 12	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
12	Output contact 13	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
13	Output contact 14	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
14	Virtual Input 1	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
15	Virtual Input 2	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
16	Virtual Input 3	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
17	Virtual Input 4	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
18	Virtual Input 5	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s

Point Index	Name	Supported Control Operations											Name for State when value is 0	Name for State when value is 1	Default Class Assigned to Events (1, 2, 3 or none)		Description
		Select/Operate	Direct Operate	Direct Operate - No Ack	Pulse On / NUL	Pulse Off	Latch On / NUL	Latch Off / NUL	Trip	Close	Count > 1	Cancel Currently Running Operation			Change	Command	
19	Virtual Input 6	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
20	Virtual Input 7	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
21	Virtual Input 8	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
22	Virtual Input 9	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
23	Virtual Input 10	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
24	Virtual Input 11	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
25	Virtual Input 12	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
26	Virtual Input 13	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
27	Virtual Input 14	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
28	Virtual Input 15	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
29	Virtual Input 16	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
30	Virtual Input 17	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
31	Virtual Input 18	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
32	Virtual Input 19	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
33	Virtual Input 20	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
34	Virtual Input 21	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
35	Virtual Input 22	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
36	Virtual Input 23	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
37	Virtual Input 24	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
38	Virtual Input 25	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
39	Virtual Input 26	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
40	Virtual Input 27	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
41	Virtual Input 28	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
42	Virtual Input 29	Y	Y	Y	Y	-	Y	Y	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
43	Virtual Input 30	Y	Y	Y	Y	-	Y	-	-	-	-	-	Inactive	Active	None	None	Pulse duration fixed at 1 s
44*	Output Contact 15	Y	Y	Y	Y	-	Y	-	-	-	-	-	Open	Closed	None	None	Pulse duration fixed at 1 s
45*	Output Contact 16	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	

Point Index	Name	Supported Control Operations											Name for State when value is 0	Name for State when value is 1	Default Class Assigned to Events (1, 2, 3 or none)		Description
		Select/Operate	Direct Operate	Direct Operate - No Ack	Pulse On / NUL	Pulse Off	Latch On / NUL	Latch Off / NUL	Trip	Close	Count > 1	Cancel Currently Running Operation			Change	Command	
46*	Output Contact 17	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
47*	Output Contact 18	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
48*	Output Contact 19	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
49*	Output Contact 20	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	
50*	Output Contact 21	-	-	-	-	-	-	-	-	-	-	-	Open	Closed	None	None	

2.3 Analog Input Points	Capabilities	Current Value	If configurable, list methods
2.3.1 Static Variation reported when variation 0 requested:	☐ Variation 1 - 32-bit with flag ☐ Variation 2 - 16-bit with flag ☐ Variation 3 - 32-bit without flag ☒ Variation 4 - 16-bit without flag ☐ Variation 5 - single-precision floating point with flag ☐ Variation 6 - double-precision floating point with flag ☐ Based on point Index (add column to table below)		
2.3.2 Event Variation reported when variation 0 requested:	☐ Variation 1 - 32-bit without time ☒ Variation 2 - 16-bit without time ☐ Variation 3 - 32-bit with time ☐ Variation 4 - 16-bit with time ☐ Variation 5 - single-precision floating point w/o time ☐ Variation 6 - double-precision floating point w/o time ☐ Variation 7 - single-precision floating point with time ☐ Variation 8 - double-precision floating point with time ☐ Based on point Index (add column to table below)		
2.3.3 Event reporting mode:	☐ Only most recent ☒ All events		
2.3.4 Analog Inputs Included in Class 0 response:	☒ Always ☐ Never ☐ Only if point is assigned to Class 1, 2, or 3 ☐ Based on point Index (add column to table below)		
2.3.5 How Deadbands are set:	☐ A. Global Fixed ☐ B. Configurable through DNP ☒ C. Configurable via other means ☐ D. Other, explain _____ ☐ Based on point Index - column specifies which of the options applies, B, C, or D		T-PRO Offliner
2.3.6 Analog Deadband Algorithm: simple - just compares the difference from the previous reported value	☒ Simple ☐ Integrating ☐ Other, explain _____		
2.3.7 Definition of Analog Input Point List:	☐ Fixed, list shown in table below ☒ Configurable ☐ Other, explain_____	Complete list is shown in the table below; points excluded from the default configuration are marked with '*'	T-PRO Offliner

NOTES

1. Analog Inputs are scanned with 500 ms resolution.

2. Nominal values in calculations for the following table are based on 69V secondary voltage * PT ratio for voltage channels, and either 1 A or 5A secondary current * CT ratio for current channels dependent upon the format of CT installed in the T-PRO.

3. Analog Input data points are user selectable; the data points available in the device for any given Analog Input point selection can be obtained through the T-PRO Offliner software (see SCADA Setting Summary).

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution[c] (default/ maximal)	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
0	Va Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	kV	0.1 / 0.00001	
1	Va Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
2	Vb Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	kV	0.1 / 0.00001	
3	Vb Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
4	Vc Magnitude	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	kV	0.1 / 0.00001	
5	Vc Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
6	Voltage (V1)	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	kV	0.1 / 0.00001	
7	I1 positive	2	0	Configurable	1.0 / (0.01 – 1000)	0.0	A	1.0 / 0.01	
8	P	2	0	Configurable	0.1 / (0.00001- 1.0)	0.0	MW	0.1 / 0.00001	
9	Q	2	00	Configurable	0.1 / (0.00001- 1.0)	0.0	Mvar	0.1 / 0.00001	
10	I1a Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
11	I1a Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
12	I1b Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
13	I1b Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
14	I1c Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
15	I1c Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
16	I2a Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
17	I2a Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
18	I2b Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
19	I2b Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
20	I2c Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
21	I2c Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
22	I3a Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
23	I3a Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
24	I3b Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
25	I3b Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
26	I3c Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
27	I3c Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
28	I4a Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
29	I4a Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
30	I4b Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
31	I4b Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
32	I4c Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution[c] (default/ maximal)	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
33	I4c Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
34	I5a Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
35	I5a Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
36	I5b Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
37	I5b Angle	2	0	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
38	I5c Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
39	I5c Angle	2	0	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
40	HV IA Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
41	HV IA Angle	2	0	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
42	HV IB Magnitude	2	-18,000	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
43	HV IB Angle	2	0	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
44	HV IC Magnitude	2	-18,000	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
45	HV IC Angle	2	0	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
46	LV IB Magnitude	2	-18,000	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
47	LV IA Angle	2	0	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
48	LVb Current Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
49	LV IB Angle	2	0	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
50	LV IC Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
51	LV IC Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
52	TV IA Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
53	TV IA Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
54	TV IB Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
55	TV IB Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
56	TV IC Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
57	TV IC Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0.0	Degrees	0.1 / 0.01	
58	Ia Operating	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
59	Ib Operating	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
60	Ic Operating	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
61	Ia Restraint	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
62	Ib Restraint	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
63	Ic Restraint	2	0	Configurable	1.0 / (0.01 - 1000)	0.0	A	1.0 / 0.01	
64	Frequency	2	0	Configurable	0.01 / (0.001 – 1.0)	0.0	Hz	0.01 / 0.001	
65	DC1	2	0	Configurable	0.01 / (0.00001- 1.0)	0.0	mA	0.01 / 0.00001	
66	DC2	2	0	Configurable	0.01 / (0.00001- 1.0)	0.0	mA	0.01 / 0.00001	
67	49 HV Current	2	0	200	0.01 / (0.01 – 1.0)	0.0	p.u.	0.01 / 0.01	
68	49 LV Current	2	0	200	0.01 / (0.01 – 1.0)	0.0	p.u.	0.01 / 0.01	
69	49 TV Current	2	0	200	0.01 / (0.01 – 1.0)	0.0	p.u.	0.01 / 0.01	
70	Ambient Temperature	2	-500	400	0.1 / (0.1 – 1.0)	0.0	C	0.1 / 0.1	
71	Top Oil Temperature	2	-300	2000	0.1 / (0.1 – 1.0)	0.0	C	0.1 / 0.1	
72	Hot Spot Temperature	2	-300	2500	0.1 / (0.1 – 1.0)	0.0	C	0.1 / 0.1	
73	Loss of Life	2	0	10000	0.01 (0.01 – 1.0)	0.0	%	0.01 / 0.01	
74	51 Pickup Level	2	0	250	0.01 (0.01 – 1.0)	0.0	p.u.	0.01 / 0.01	
75	THD	2	0	Configurable	0.01 / (0.01- 1.0)	0.0	%	0.01 / 0.01	
76	TOEWS Minutes to trip	2	0	30	1.0	0.0	Minutes	1.0 / 1.0	
77	Self Check Fail	2	0	65,535	1.0	0.0	NA	1.0 / 1.0	
78	Accumulated IA*IA*t	2	0	65,535	0.001 / (0.001 – 1.0)	0.0	kA*kA*s	0.001 / 0.001	
79	Accumulated IB*IB*t.	2	0	65,535	0.001 / (0.001 1.0)		kA*kA*s	0.001 / 0.001	
80	Accumulated IC*IC*t.	2	0	65,535	0.001 / (0.001 1.0)		kA*kA*s	0.001 / 0.001	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution[c] (default/ maximal)	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
81	Accumulated Through Fault count	2	0	65,535	1.0	0.0	NA	1.0 / 1.0	
82	Active Setting Group	2	1	8	1.0	0.0	NA	1.0	
83	S	2	0	Configurable	0.1 / (0.00001- 1.0)	0	MVA	0.1 / 0.00001	
84	PF	2	-1000	1000	0.01 / (0.001- 0.1)	0	NA	0.01 / 0.001	
85	Voltage (V0)	2	0	Configurable	0.1 / (0.00001- 1.0)	0	kV	0.1 / 0.00001	
86	Voltage (V2)	2	0	Configurable	0.1 / (0.00001- 1.0)	0	kV	0.1 / 0.00001	
87	I1 zero	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
88	I1 negative	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
89	I2 positive	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
90	I2 zero	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
91	I2 negative	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
92	I3 positive	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
93	I3 zero	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
94	I3 negative	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
95	I4 positive	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
96	I4 zero	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
97	I4 negative	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
98	I5 positive	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
99	I5 zero	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
100	I5 negative	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
101	HV 3I0 Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
102	HV 3I0 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0	degrees	1.0 / 0.01	
103	LV 3I0 Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
104	LV 3I0 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0	degrees	1.0 / 0.01	
105	TV 3I0 Magnitude	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
106	TV 3I0 Angle	2	-18,000	18,000	0.1 / (0.01 - 1.0)	0	degrees	1.0 / 0.01	
107	HV REF IO	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
108	LV REF IO	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
109	TV REF IO	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
110	HV REF IR	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
111	LV REF IR	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
112	TV REF IR	2	0	Configurable	1.0 / (0.01 - 1000)	0	A	1.0 / 0.01	
113*	HV IA 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
114*	HV IB 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
115*	HV IC 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
116*	LV IA 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
117*	LV IB 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
118*	LV IC 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
119*	TV IA 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
120*	TV IB 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
121*	TV IC 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
122*	I1a 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
123*	I1b 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	

Point Index	Name	Default Class Assigned to Events (1, 2, 3 or none)	Transmitted Value[a]		Scaling[b]		Units	Resolution[c] (default/ maximal)	Description
			Minimum	Maximum[d]	Multiplier (default/ (range))	Offset			
124*	I1c 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
125*	I2a 2nd Harmonic Magnitude	2	0		0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
126*	I2b 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
127*	I2c 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
128*	I3a 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
129*	I3b 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
130*	I3c 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
131*	I4a 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
132*	I4b 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
133*	I4c 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
134*	I5a 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
135*	I5b 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
136*	I5c 2nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
137*	I1a 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
138*	I1b 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
139*	I1c 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
140*	I2a 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
141*	I2b 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
142*	I2c 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
143*	I3a 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
144*	I3b 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
145*	I3c 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
146*	I4a 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
147*	I4b 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
148*	I4c 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
149*	I5a 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
150*	I5b 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
151*	I5c 5nd Harmonic Magnitude	2	0	Configurable	0.01 / (0.01- 1.0)	0	%	0.01 / 0.01	
152*	Pa	2	0	Configurable	0.1 / (0.00001- 1.0)	0	MW	0.1 / 0.00001	
153*	Pb	2	0	Configurable	0.1 / (0.00001- 1.0)	0	MW	0.1 / 0.00001	
154*	Pc	2	0	Configurable	0.1 / (0.00001- 1.0)	0	MW	0.1 / 0.00001	
155*	Qa	2	0	Configurable	0.1 / (0.00001- 1.0)	0	Mvar	0.1 / 0.00001	
156*	Qb	2	0	Configurable	0.1 / (0.00001- 1.0)	0	Mvar	0.1 / 0.00001	
157*	Qc	2	0	Configurable	0.1 / (0.00001- 1.0)	0	Mvar	0.1 / 0.00001	
158*	Sa	2	0	Configurable	0.1 / (0.00001- 1.0)	0	MVA	0.1 / 0.00001	
159*	Sb	2	0	Configurable	0.1 / (0.00001- 1.0)	0	MVA	0.1 / 0.00001	
160*	Sc	2	0	Configurable	0.1 / (0.00001- 1.0)	0	MVA	0.1 / 0.00001	
161*	PFa	2	-1000	1000	0.01 / (0.001- 0.1)	0	NA	0.01 / 0.001	
162*	PFb	2	-1000	1000	0.01 / (0.001- 0.1)	0	NA	0.01 / 0.001	
163*	PFc	2	-1000	1000	0.01 / (0.001- 0.1)	0	NA	0.01 / 0.001	

a. The minimum and maximum transmitted values are the lowest and highest values that the outstation will report in DNP analog input objects. These values are integers if the outstation transmits only integers. If the outstation is capable of transmitting both integers and floating-point, then integer and floating-point values are required for the minimums and maximums.
   For example, a pressure sensor is able to measure 0 to 500 kPa. The outstation provides a linear conversion of the sensor's output signal to integers in the range of 0 to 25000 or floating-point values of 0 to 500.000. The sensor and outstation are used in an application where the maximum possible pressure is 380 kPa. For this input, the minimum transmitted value would be stated as 0 / 0.0 and the maximum transmitted value would be stated as 19000 / 380.000.
b. The scaling information for each point specifies how data transmitted in integer variations (16 bit and 32 bit) is converted to engineering units when received by the Master (i.e. scaled according to the equation: scaled value = multiplier * raw + offset). Scaling is not applied to Floating point variations since they are already transmitted in engineering units.
c. Resolution is the smallest change that may be detected in the value due to quantization errors and is given in the units shown in the previous column. This parameter does not represent the accuracy of the measurement.
d. Maximal values are calculated as (2 * Configured Nominal / Multiplier) for voltage channels and as (40 * Configured Nominal / Multiplier) for current channels (see Note 2 above for the nominal definitions).

2.4 Octet String Points		Capabilities	Current Value	If configurable, list methods
2.4.1	Event reporting mode *:	☐ Only most recent ☒ All events		
2.4.2	Octet Strings Included in Class 0 response:	☐ Always ☒ Never ☐ Only if point is assigned to Class 1, 2, or 3 ☐ Based on point Index (add column to table below)		
2.4.3	Definition of Octet String Point List:	☐ Fixed, list shown in table below ☐ Configurable (current list may be shown in table below) ☒ Other, explain Used for Event Log access as described below		

* Object 110 and 111 are Octet String Object used to provide access to the Event Log text of the relay. Object 110 always contains the most recent event in the relay. Object 111 is the corresponding change event object.

As stated in the DNP specifications, the variation of the response object represents the length of the string. The string represents the ASCII values of the event text.

Implementation Table

The following implementation table identifies which object groups and variations, function codes and qualifiers the device supports in both requests and responses. The Request columns identify all requests that may be sent by a Master, or all requests that must be parsed by an Outstation. The Response columns identify all responses that must be parsed by a Master, or all responses that may be sent by an Outstation.

NOTE

The implementation table must list all functionality required by the device whether Master or Outstation as defined within the DNP3 IED Conformance Test Procedures. Any functionality beyond the highest subset level supported is indicated by highlighted rows. Any Object Groups not provided by an outstation or not processed by a Master are indicated by ~~strikethrough~~ (note these Object Groups will still be parsed).

DNP Object Group & Variation			Request Outstation parses		Response Outstation can issue	
Group Num	**Var Num**	**Description**	**Function Codes (dec)**	**Qualifier Codes (hex)**	**Function Codes (dec)**	**Qualifier Codes (hex)**
1	0	Binary Input - Any Variation	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
1	1	Binary Input - Packed format	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
1	2	Binary Input - With flags	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
2	0	Binary Input Event - Any Variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response)	17, 28 (index)
2	1	Binary Input Event - Without time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) ~~130 (unsol. resp)~~	17, 28 (index)
2	2	Binary Input Event - With absolute time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) ~~130 (unsol. resp)~~	17, 28 (index)
2	3	Binary Input Event - With relative time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) ~~130 (unsol. resp)~~	17, 28 (index)
10	0	Binary Output - Any Variation	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
10	2	Binary Output - Output Status with flag	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
12	1	Binary Command - Control relay output block (CROB)	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, no ack)	17, 28 (index)	129 (response)	Echo of request

DNP Object Group & Variation			Request Outstation parses		Response Outstation can issue	
Group Num	**Var Num**	**Description**	**Function Codes (dec)**	**Qualifier Codes (hex)**	**Function Codes (dec)**	**Qualifier Codes (hex)**
20	0	~~Counter - Any Variation~~	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz. cl. noack)	06 (no range, or all)	129 (response)	
20	1	~~Counter - 32 bit with flag~~			129 (response)	~~00, 01 (start-stop)~~
20	2	~~Counter - 16 bit with flag~~			129 (response)	~~00, 01 (start-stop)~~
20	5	~~Counter - 32 bit without flag~~			129 (response)	~~00, 01 (start-stop)~~
20	6	~~Counter - 16 bit without flag~~			129 (response)	~~00, 01 (start-stop)~~
21	0	~~Frozen Counter - Any Variation~~	1 (read)	06 (no range, or all)		
21	1	~~Frozen Counter - 32 bit with flag~~			129 (response)	~~00, 01 (start-stop)~~
21	2	~~Frozen Counter - 16 bit with flag~~			129 (response)	~~00, 01 (start-stop)~~
21	9	~~Frozen Counter - 32 bit without flag~~			129 (response)	~~00, 01 (start-stop)~~
21	10	~~Frozen Counter - 16 bit without flag~~			129 (response)	~~00, 01 (start-stop)~~
22	0	~~Counter Event - Any Variation~~	1 (read)	06 (no range, or all) 07, 08 (limited qty)		
22	1	~~Counter Event - 32 bit with flag~~			129 (response) ~~130 (unsol. resp)~~	~~17, 28 (index)~~
22	2	~~Counter Event - 16 bit with flag~~			129 (response) ~~130 (unsol. resp)~~	~~17, 28 (index)~~
30	0	Analog Input - Any Variation	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
30	1	Analog Input - 32-bit with flag	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
30	2	Analog Input - 16-bit with flag	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
30	3	Analog Input - 32-bit without flag	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
30	4	Analog Input - 16-bit without flag	1 (read)	06 (no range, or all) 00, 01 (start-stop) 07, 08 (limited qty) 17, 28 (index)	129 (response)	00, 01 (start-stop)
32	0	Analog Input Event - Any Variation	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response)	17, 28 (index)
32	1	Analog Input Event - 32-bit without time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) ~~130 (unsol. resp)~~	17, 28 (index)
32	2	Analog Input Event - 16-bit without time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response) ~~130 (unsol. resp)~~	17, 28 (index)
32	3	Analog Input Event - 32-bit with time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response)	17, 28 (index)
32	4	Analog Input Event - 16-bit with time	1 (read)	06 (no range, or all) 07, 08 (limited qty)	129 (response)	17, 28 (index)
40	0	~~Analog Output Status - Any Variation~~	1 (read)	06 (no range, or all)	129 (response)	

DNP Object Group & Variation			Request Outstation parses		Response Outstation can issue	
Group Num	**Var Num**	**Description**	**Function Codes (dec)**	**Qualifier Codes (hex)**	**Function Codes (dec)**	**Qualifier Codes (hex)**
40	2	~~Analog Output Status - 16-bit with flag~~			129 (response)	~~00, 01 (start-stop)~~
41	2	~~Analog Output - 16-bit~~	3 (select) 4 (operate) 5 (direct op) 6 (dir. op, no ack)	17, 28 (index)	129 (response)	~~Echo of request~~
50	1	~~Time and Date - Absolute time~~	2 (write)	07 (limited qty = 1)	129 (response)	
51	1	~~Time and Date CTO - Absolute time, synchronized~~			~~129 (response)~~ ~~130 (unsol. resp)~~	~~07 (limited qty) (qty = 1)~~
51	2	Time and Date CTO - Absolute time, unsynchronized			129 (response) ~~130 (unsol. resp)~~	07 (limited qty) (qty = 1)
52	1	Time Delay - Coarse			129 (response)	07 (limited qty) (qty = 1)
52	2	~~Time delay - Fine~~			~~129 (response)~~	~~07 (limited qty) (qty = 1)~~
60	1	Class Objects - Class 0 data	1 (read)	06 (no range, or all)	129 (response)	00, 01 (start-stop)
60	2	Class Objects - Class 1 data	1 (read)	06 (no range, or all)	129 (response)	17, 28 (index)
60	3	Class Objects - Class 2 data	1 (read)	06 (no range, or all)	129 (response)	17, 28 (index)
60	4	Class Objects - Class 3 data	1 (read)	06 (no range, or all)	129 (response)	17, 28 (index)
80	1	Internal Indications - Packet format	2 (write)	00 (start-stop) (index = 7)	129 (response)	
110	0	Octet string	1 (read)	06 (no range, or all)	129 (response)	07 (limited qty)
111	0	Octet string event	1 (read)	06 (no range, or all)	129 (response)	07 (limited qty)
No Object (function code only)			13 (cold restart)		129 (response)	
No Object (function code only)			14 (warm restart)		129 (response)	
No Object (function code only)			23 (delay meas.)		129 (response)	

Appendix G Mechanical Drawings

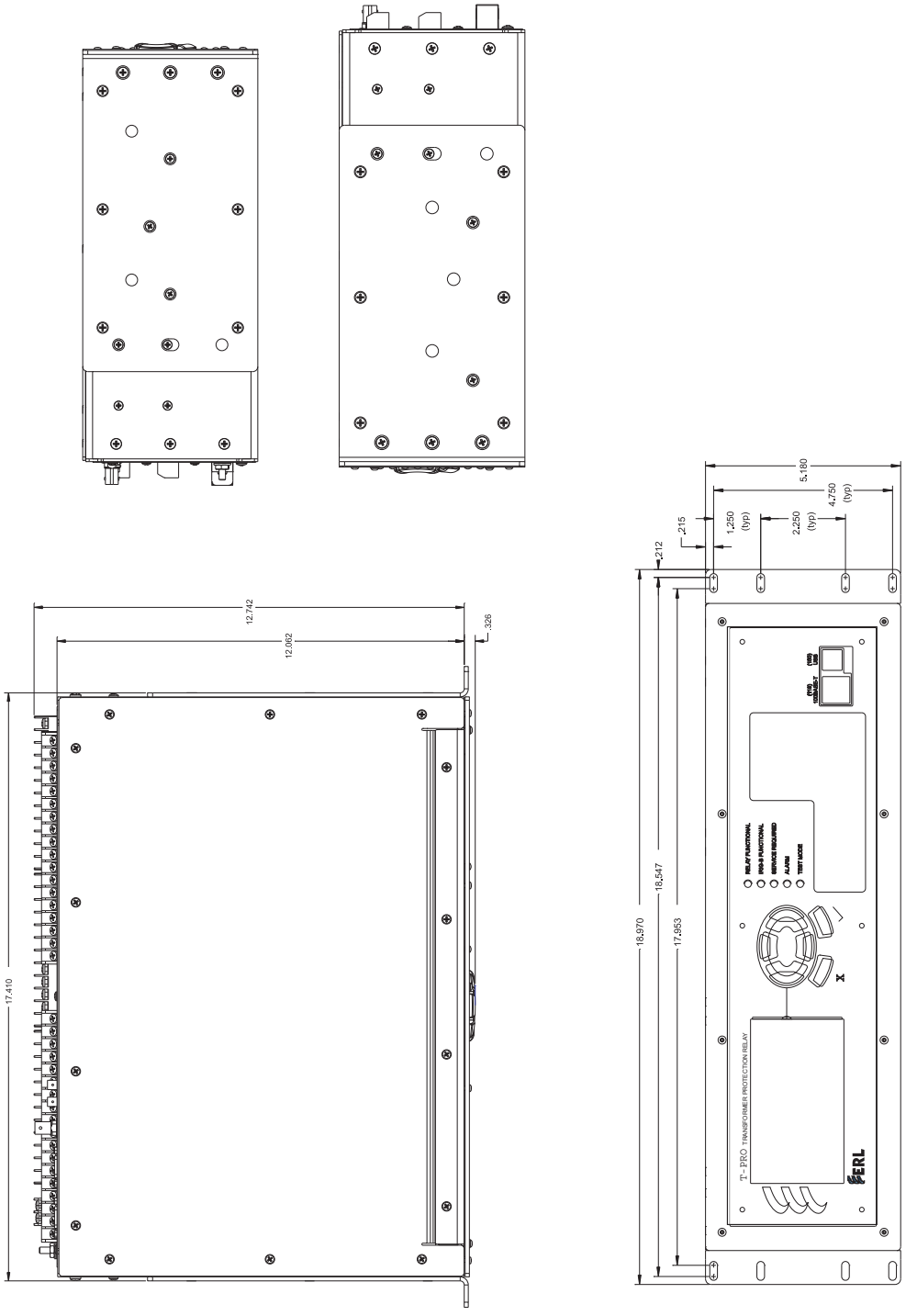


Figure G.1: Mechanical Drawing (3U)

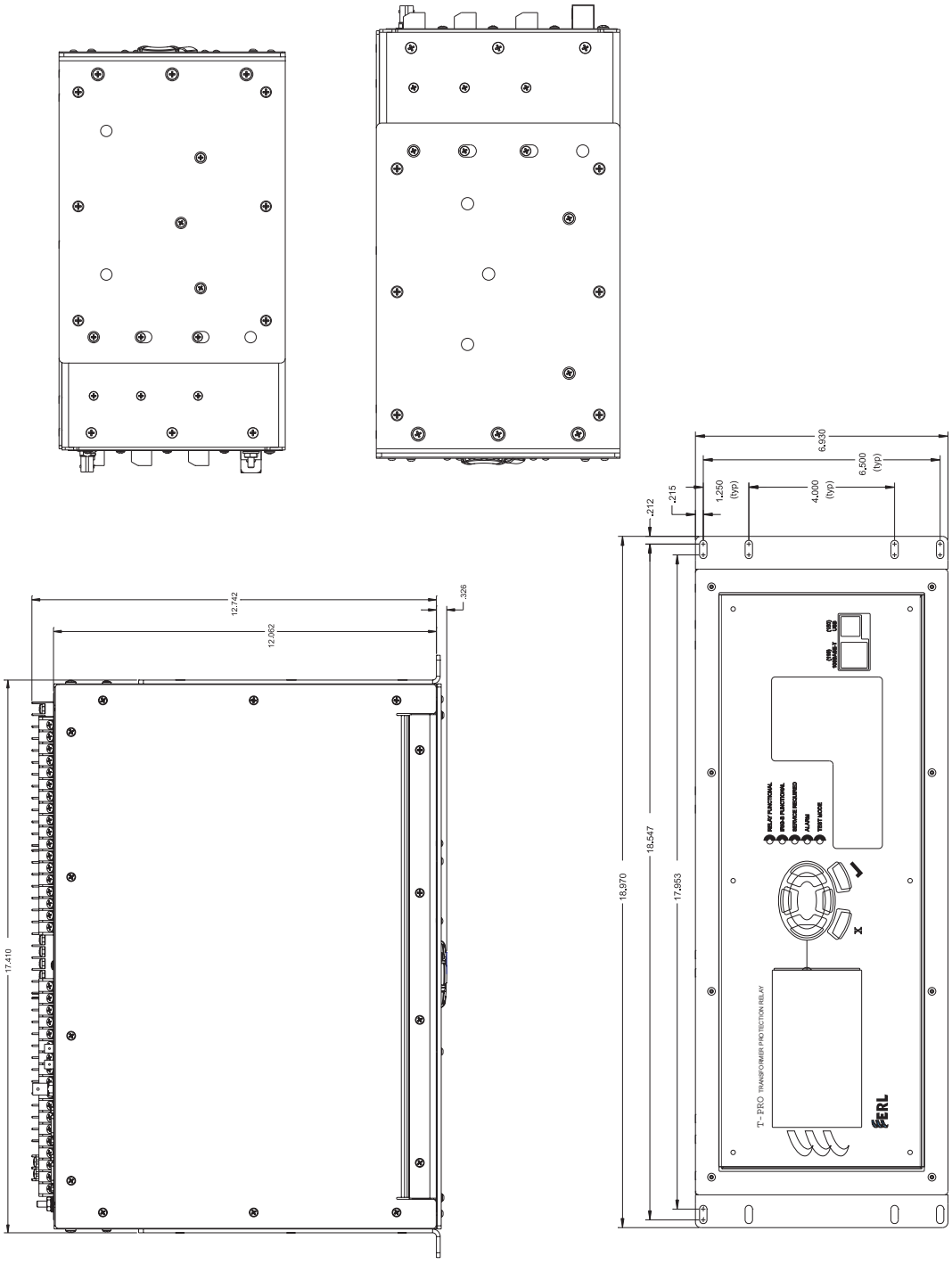


Figure G.2: Mechanical Drawing (4U)

Appendix H Rear Panel Drawings

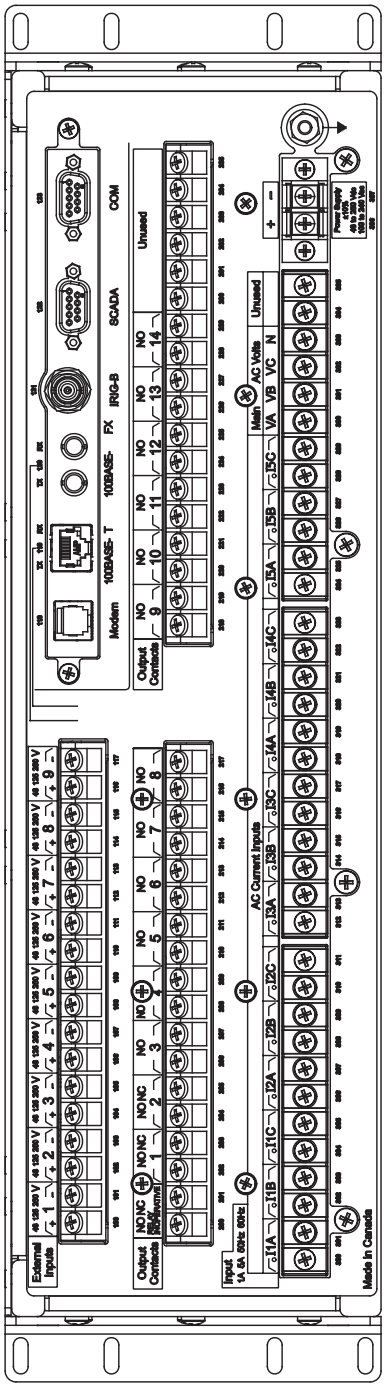


Figure H.1: Rear Panel (3U)

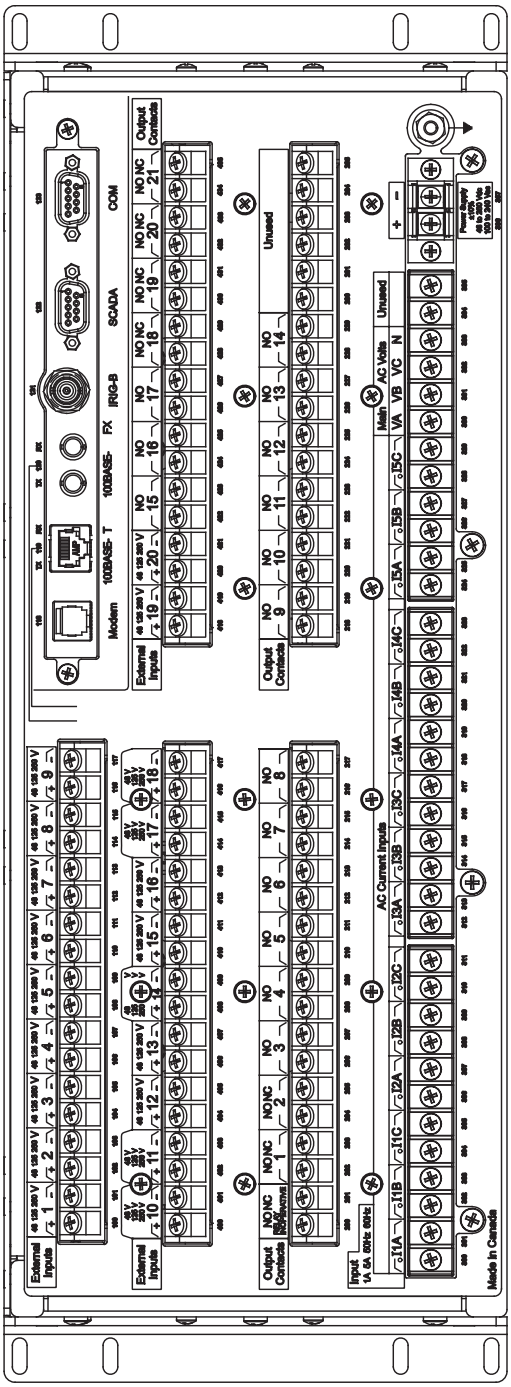


Figure H.2: Rear Panel (4U)

Appendix I AC Schematic Drawing

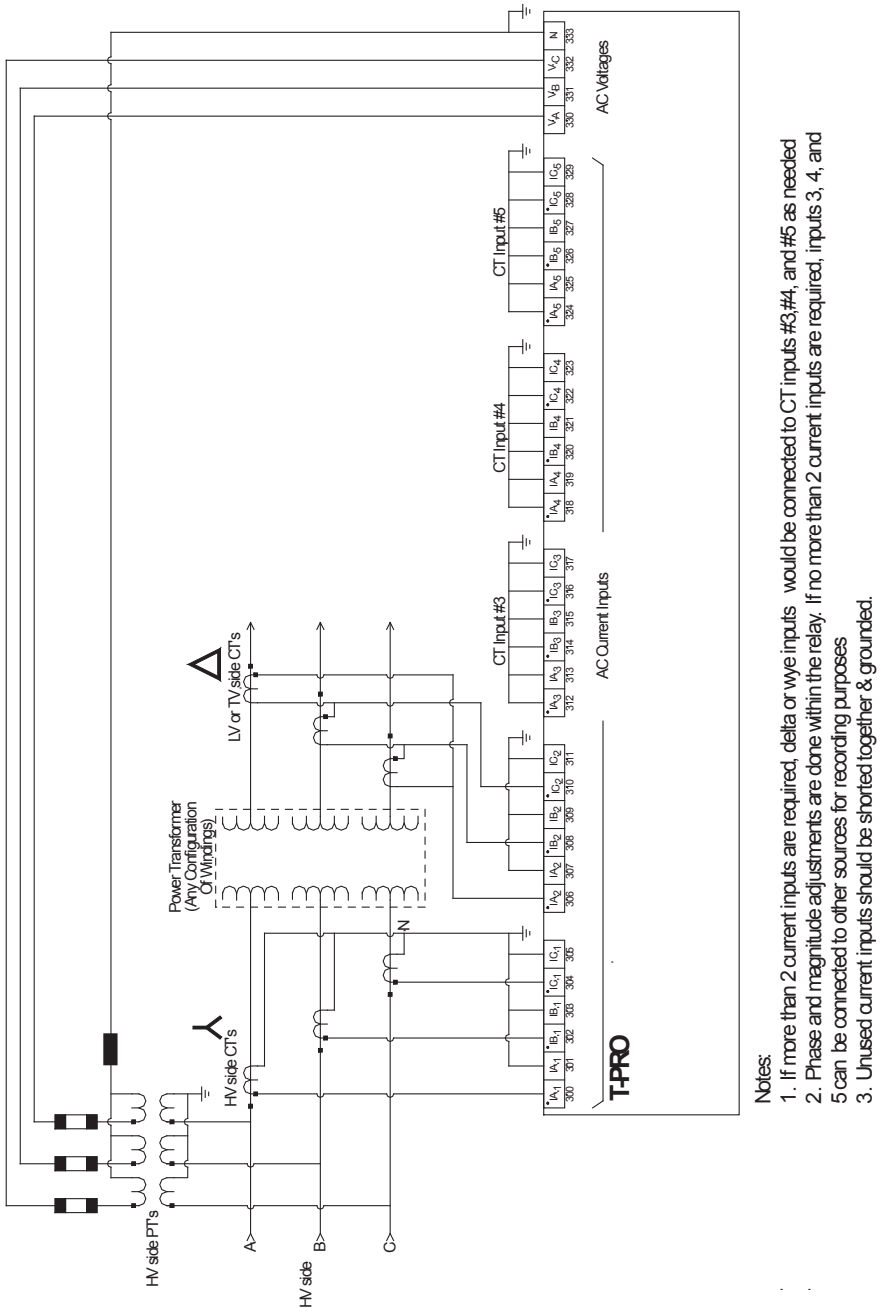

HV side PT's
HV side CT's
Power Transformer (Any Configuration Of Windings)
LV or TV side CT's
HV side
A
B
C
N
CT Input #3
CT Input #4
CT Input #5
AC Current Inputs
AC Voltages
T-PRO
Notes:
1. If more than 2 current inputs are required, delta or wye inputs would be connected to CT inputs #3,#4, and #5 as needed
2. Phase and magnitude adjustments are done within the relay. If no more than 2 current inputs are required, inputs 3, 4, and 5 can be connected to other sources for recording purposes
3. Unused current inputs should be shorted together & grounded.

Figure I.1: T-PRO AC Schematic

Appendix J DC Schematic Drawing

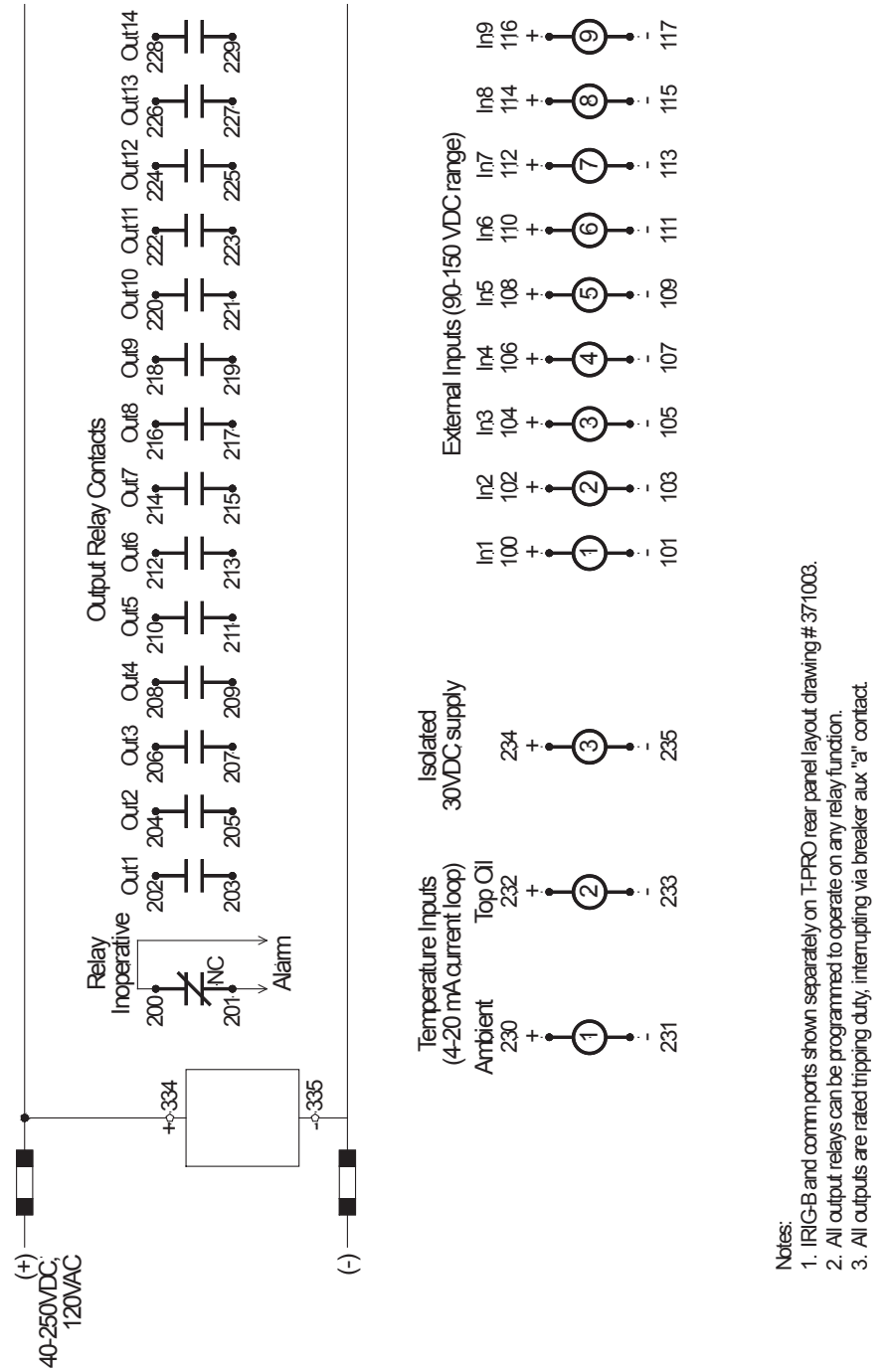

(+)
40-250VDC,
120VAC
(-)
+334
-335
Relay
Inoperative
NC
Alarm
200
201
Output Relay Contacts
Out1 Out2 Out3 Out4 Out5 Out6 Out7 Out8 Out9 Out10 Out11 Out12 Out13 Out14
202 204 206 208 210 212 214 216 218 220 222 224 226 228
203 205 207 209 211 213 215 217 219 221 223 225 227 229
Temperature Inputs
(4-20 mA current loop)
Ambient
230
231
Top Oil
232
233
Isolated
30VDC supply
234
235
External Inputs (90-150 VDC range)
In1 In2 In3 In4 In5 In6 In7 In8 In9
100 102 104 106 108 110 112 114 116
101 103 105 107 109 111 113 115 117
Notes:
1. IRIG-B and comm ports shown separately on T-PRO rear panel layout drawing # 371003.
2. All output relays can be programmed to operate on any relay function.
3. All outputs are rated tripping duty, interrupting via breaker aux "a" contact.

Figure J.1: T-PRO DC Schematic

Appendix K Function Logic Diagram

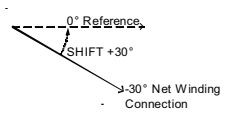
Diagram in plastic sleeve.

Appendix L Current Phase Correction Table

Current Phase Correction Table

CPC1 (for -30° or +330° Net Winding Connection)

+30° (or -330°) Shift



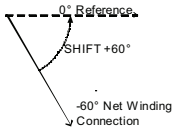
$$IA = \frac{Ia - Ib}{\sqrt{3}}$$

$$IB = \frac{Ib - Ic}{\sqrt{3}}$$

$$IC = \frac{Ic - Ia}{\sqrt{3}}$$

CPC2 (for -60° or +300° Net Winding Connection)

+60° (or -300°) Shift



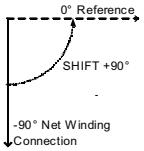
$$IA = \frac{Ia - 2Ib + Ic}{3}$$

$$IB = \frac{Ia + Ib - 2Ic}{3}$$

$$IC = \frac{-2Ia + Ib + Ic}{3}$$

CPC3 (for -90° or +270° Net Winding Connection)

+90° (or -270°) Shift



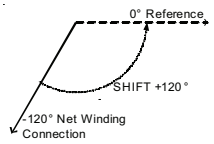
$$IA = \frac{Ic - Ib}{\sqrt{3}}$$

$$IB = \frac{Ia - Ic}{\sqrt{3}}$$

$$IC = \frac{Ib - Ia}{\sqrt{3}}$$

CPC4 (for -120 or +240 Net Winding Connection)

+120° (or -240°) Shift



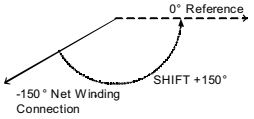
$$IA = \frac{-Ia - Ib + 2Ic}{3}$$

$$IB = \frac{2Ia - Ib - Ic}{3}$$

$$IC = \frac{-Ia + 2Ib - Ic}{3}$$

CPC5 (for -150° or +210° Net Winding Connection)

+150° (or -210°) Shift



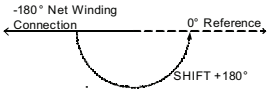
$$IA = \frac{Ic - Ia}{\sqrt{3}}$$

$$IB = \frac{Ia - Ib}{\sqrt{3}}$$

$$IC = \frac{Ib - Ic}{\sqrt{3}}$$

CPC6 (for -180° or +180° Net Winding Connection)

+180° (or -180°) Shift



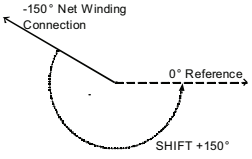
$$IA = \frac{-2Ia + Ib + Ic}{3}$$

$$IB = \frac{Ia - 2Ib + Ic}{3}$$

$$IC = \frac{Ia + Ib - 2Ic}{3}$$

CPC7 (for -210° or +150° Net Winding Connection)

+210° (or -150°) Shift



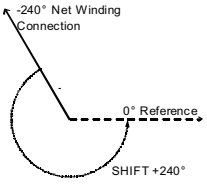
$$IA = \frac{Ib - Ia}{\sqrt{3}}$$

$$IB = \frac{Ic - Ib}{\sqrt{3}}$$

$$IC = \frac{Ia - Ic}{\sqrt{3}}$$

CPC8 (for -240° or +120° Net Winding Connection)

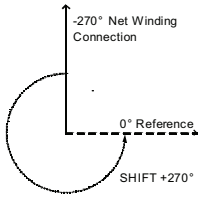
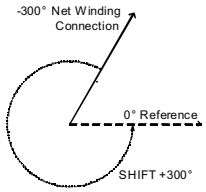
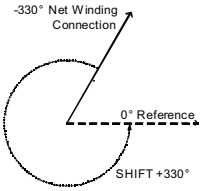
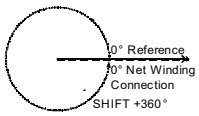
+240° (or -120°) Shift



$$IA = \frac{-Ia + 2Ib - Ic}{3}$$

$$IB = \frac{-Ia - Ib + 2Ic}{3}$$

$$IC = \frac{2Ia - Ib - Ic}{3}$$

CPC9 (for -270° or +90° Net Winding Connection)		CPC10 (for -300° or +60° Net Winding Connection)	
+270° (or -90°) Shift 	$IA = \frac{Ib - Ic}{\sqrt{3}}$ $IB = \frac{Ic - Ia}{\sqrt{3}}$ $IC = \frac{Ia - Ib}{\sqrt{3}}$	**+300° (or -60°) Shift** 	$IA = \frac{Ia + Ib - 2Ic}{3}$ $IB = \frac{-2Ia + Ib + Ic}{3}$ $IC = \frac{Ia - 2Ib + Ic}{3}$
CPC11 (for -330° or +30° Net Winding Connection)		**CPC12 (for 0° or 360° Net Winding Connection)**	
+330° (or -30°) Shift 	$IA = \frac{Ia - Ic}{\sqrt{3}}$ $IB = \frac{Ib - Ia}{\sqrt{3}}$ $IC = \frac{Ic - Ib}{\sqrt{3}}$	**0° (or -360°) Shift** 	$IA = \frac{2Ia - Ib - Ic}{3}$ $IB = \frac{-Ia + 2Ib - Ic}{3}$ $IC = \frac{-Ia - Ib + 2Ic}{3}$

Appendix M Loss of Life of Solid Insulation

The loss of life calculation equation is based on IEEE Standard C57.91-1995. The per unit rate of loss of life is called the aging acceleration factor (F_{AA}), given by

$$F_{AA} = e^{\frac{15000}{110+273} - \frac{15000}{\theta_H + 273}}$$

per unit. [Eq. (2) of C57.91-1995]

where θ_H is the hot spot temperature in degrees celsius.

For example, if θ_H = 110°C, then F_{AA} = 1;

if θ_H =117°C, then F_{AA} = 2.

The definition of "normal lifetime" for a transformer was 65,000 hours (7.42 years) in C57.115-1991. In C57.91-1995 options were given including 65,000 hours, but suggesting that 180,000 (20.55 years) hours was more reasonable. This is really a judgment call. Since the 65,000 hour (7.42 years) figure appears in both versions of the Standard, it was decided to use 7.42 years in the T-PRO software, until a more definitive statement appears.

The above equation is the same, regardless of which "end of life" value is chosen.

For example, if F_{AA} is on average equal to 0.2 (not unusual) over a period of 20 years, then the loss of life over that period would be (0.2 x 20 years)/(7.42 years) = 54%.

The equation in the previous standard (C57.115-1991) is written differently, but is identical mathematically.

C57.91-1995 is under review, as of November 2001. A new version may be issued in the year 2002.

Adaptive Overcurrent Relay Pickup Level Feature

There are two basic ideas here, based on ANSI/IEEE Standards C57.92-1981 and C57.115-1991, for Mineral Oil Immersed Power Transformers:

1 When the ambient temperature is low, a transformer can carry more load, when high, less load.

2 It is OK to exceed the transformer rated (hot spot) winding temperature, for a limited time.

The T-PRO Relay implements these ideas as follows:

When Ambient Temperature Adaptation is selected, the pickup level of the overcurrent protection follows the Allowed Loading curves below, which are calculated in accordance with the Standards. An ambient temperature probe feeds information into the back of the relay. Five different cooling types are accommodated, in accordance with the Standard.

Example 1

Suppose the transformer is 65°C rise, cooling is type 5: Forced Air Cooled (ONAN/ONAF/ONAF) and a "relative rate of loss of life" of "1" has been selected. Then the overload characteristic pickup will automatically be one per unit when the Ambient Temperature is 30°C, because that is the design condition for the transformer.

As the ambient temperature deviates from 30°C, the relay pickup will track the lower curve in the diagram, so that for example at -30°C, the overcurrent relay pickup is automatically changed to 1.4 per unit. Conversely, the transformer is automatically de-rated to about 0.93 per unit, if the ambient temperature goes to 40°C.

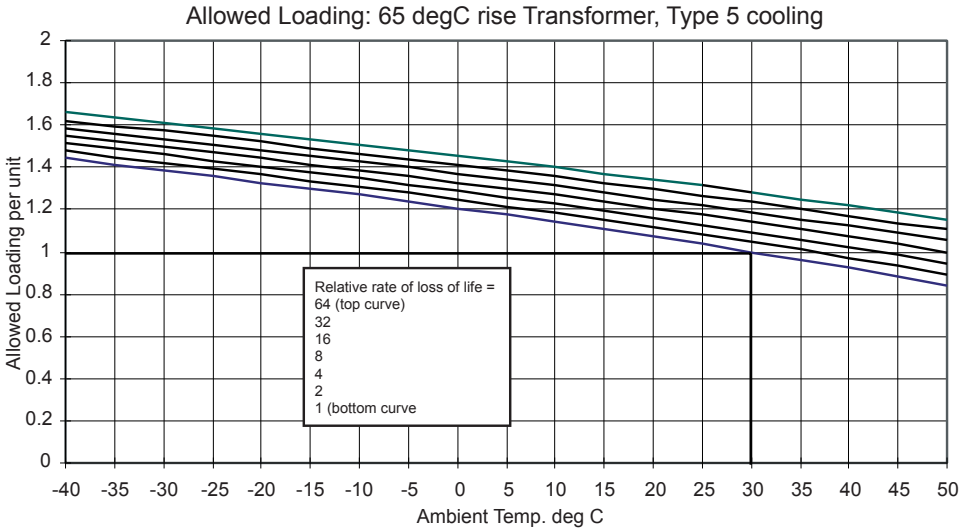


Figure M.1: Allowed Loading: 65°C Rise Transformer, Type 5 Cooling

If a "relative rate of loss of life" of "1" is chosen, and a loading just below pickup were to persist for 24 hours, "normal" i.e. design loss of life would occur. However, loading is seldom this constant.

Thus it can be seen that higher rates of loss of life might be reasonably accepted (2, 4, 8, 16, 32). Under such conditions, the continued "trend logging" of internal temperatures and accumulated loss of life become valuable features of the T-PRO Relay.

Example 2

Refer to the same curve in “Example 1” in Appendix M. Suppose for the same transformer a “relative rate of loss of life” of “8” has been selected. First, note that this corresponds to a steady-state hot spot temperature of 130°C (see Table “65°C Rise Transformer” in Appendix M on page Appendix M-6), not a dangerous level. Suppose also that the ambient temperature is 35°C. From the curves, the Allowed Loading is 1.1 per unit. In other words, the inverse-time overcurrent relay pickup will adapt to 1.1 per unit. [At an ambient of -25°C, a 48% overload trip level would pertain.]

What does this mean? The meaning is that at just under this trip level, the transformer insulation is deteriorating at just under 8 times the normal rate. This is not a problem unless the situation is never ‘balanced’ by lower operating levels, as is usually the case.

Another way of looking at this is that the adaptive feature, with settings of rate of loss of life greater than normal, allows temporary overloads.

Note that the shape of the inverse-time curve above 2 per unit current is not affected, as shown in for details see Figure M.2: Adaptive Pickup Characteristic on page M-3.

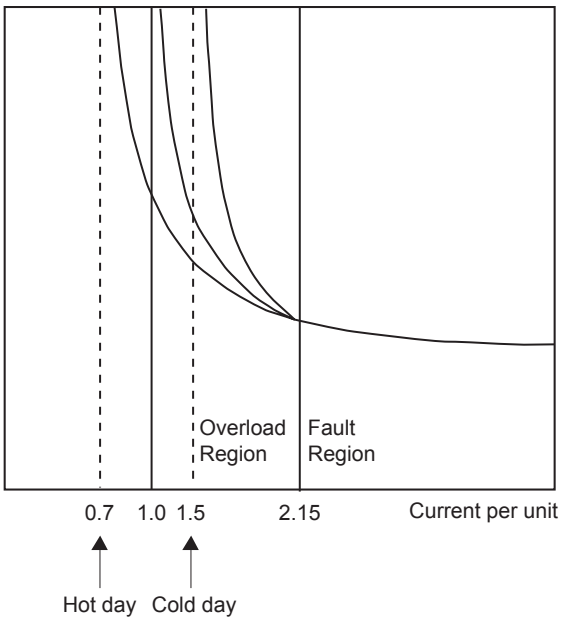


Figure M.2: Adaptive Pickup Characteristic

The “Trend Logging” feature of the T-PRO relay allows you to keep track of the accumulated loss of life to ensure that overloads are not causing a long term problem.

Overloading Curves for 65°C Rise Transformers

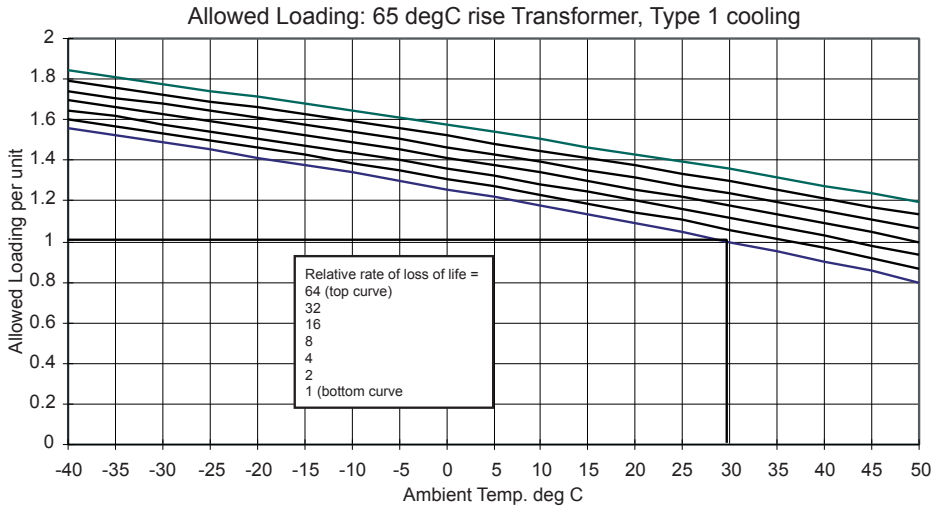


Figure M.3: Allowed Loading: 65°C Rise Transformer, Type 1 Cooling

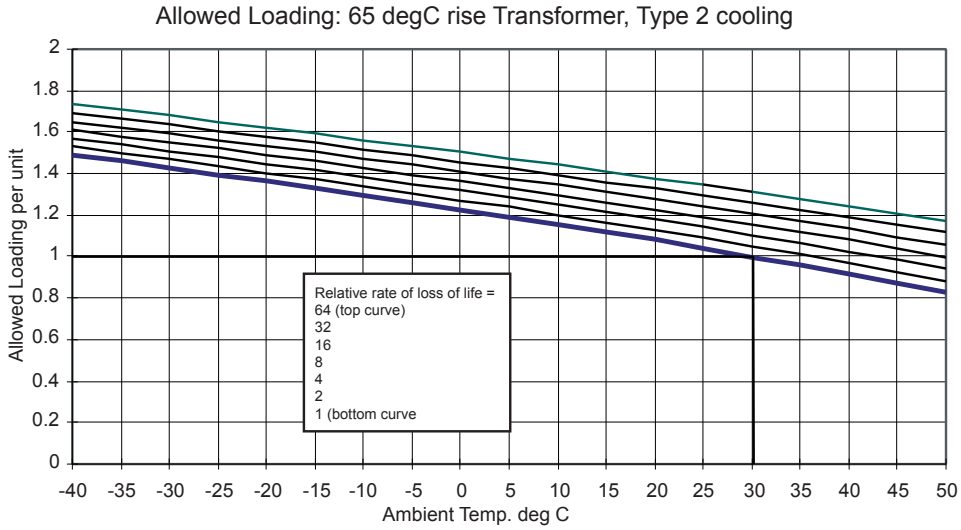


Figure M.4: Allowed Loading: 65°C Rise Transformer, Type 2 Cooling

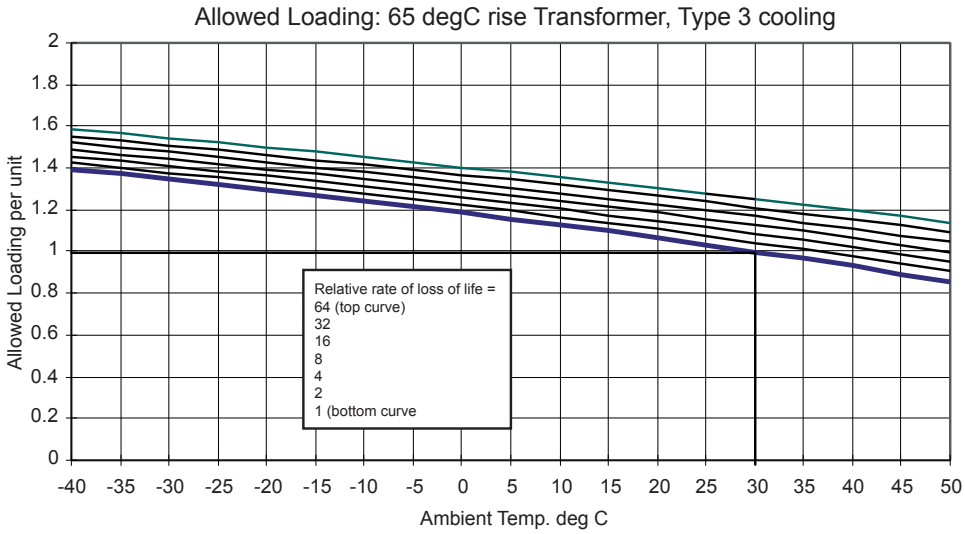


Figure M.5: Allowed Loading: 65°C Rise Transformer, Type 3 Cooling

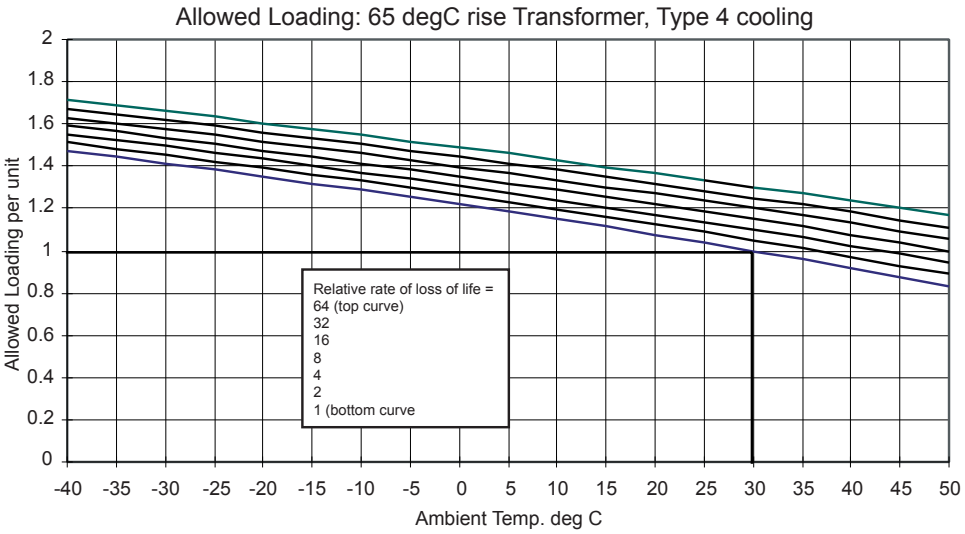


Figure M.6: Allowed Loading: 65°C Rise Transformer, Type 4 Cooling

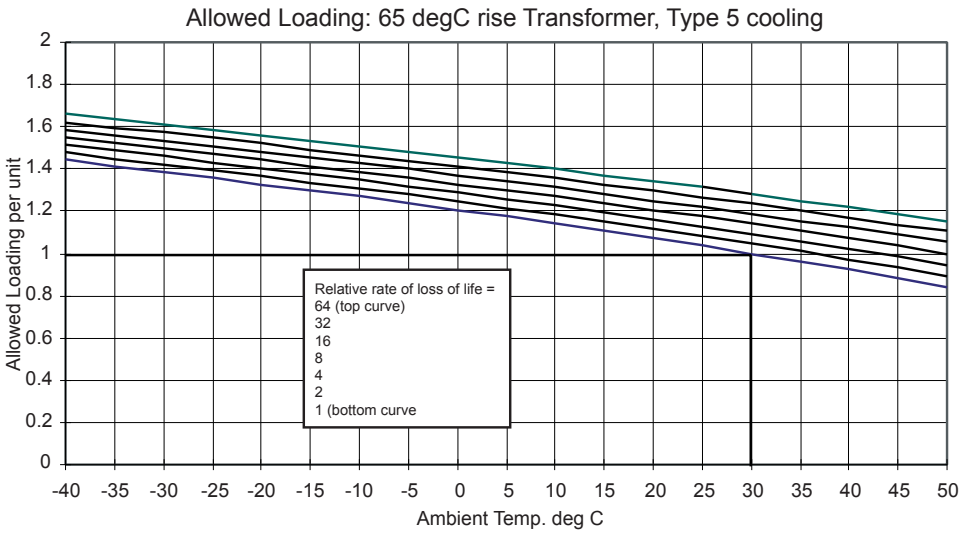


Figure M.7: Allowed Loading: 65°C Rise Transformer, Type 5 Cooling

The above curves are for 65°C rise transformers. Curves for 55°C rise transformers can be supplied on request.

Each "Relative rate of loss of life" curve is related directly to a specific hot spot temperature as follows:

65°C Rise Transformer						
Relative Rate of Loss of Life	1	2	4	8	16	32
Hot Spot Temperature °C	110	116	123	130	137	145

55°C Rise Transformer						
Relative Rate of Loss of Life	1	2	4	8	16	32
Hot Spot Temperature °C	95	101	107	113	120	127

Appendix N Top Oil and Hot Spot Temperature Calculation

The parameters used in calculating the Top Oil and Hot Spot (Winding) temperatures as functions of the ambient temperature and the load current, are as shown below [Based on IEEE/ANSI Standards C57.115-1991 and C57.92-1981].

Parameters for 65°C Rise Transformers					
Cooling Type	OA or OW (Type 1)*	FA 133% or less (Type 2)	FA more than 133% (Type 4)	Non-directed ODAF or ODWF (Type 5)	Directed ODAF or ODWF (Type 3)
$\Delta\theta_{H,R}$ °C	25	30	35	35	35
$\Delta\theta_{TO,R}$ °C	55	50	45	45	45
τ_{TO} hours	3.0	2.0	1.25	1.25	1.25
τ_{W} hours	0.08	0.08	0.08	0.08	0.08
R	3.2	4.5	6.5	6.5	6.5
m	0.8	0.8	0.8	0.8	1.0
n	0.8	0.9	0.9	1.0	1.0

Parameters for 55°C Rise Transformers					
Cooling Type	OA or OW	FA 133% or less	FA more than 133%	Non-directed ODAF or ODWF	Directed ODAF or ODWF
$\Delta\theta_{H,R}$ °C	20	25	28	28	28
$\Delta\theta_{TO,R}$ °C	45	40	37	37	37
τ_{TO} hours	3.0	2.0	1.25	1.25	1.25
τ_{W} hours	0.08	0.08	0.08	0.08	0.08
R	3.0	3.5	5.0	5.0	5.0
m	0.8	0.8	0.8	0.8	1.0
n	0.8	0.9	0.9	1.0	1.0

The meanings of the symbols, and the equations used are as follows:

$\Delta\theta_{H,R}$	rated hot spot rise over top oil in °C
$\Delta\theta_{TO,R}$	rated top oil rise over ambient in °C
τ_{TO}	top oil rise time constant in hours
τ_{W}	hot spot (winding) rise time constant in hours
R	ratio of full load (rated) copper loss to rated iron loss, dimensionless
m	exponent relating load level to hot spot rise, dimensionless
n	exponent relating load level to top oil rise, dimensionless

The newest version of this Standard, at the time of writing (1998), is C57.91-1995. The only numerical difference in the new table is for Non-Directed OFAF or OFWF cooling: n = 0.9 (rather than 1.0).

Also, in the new standard, it is recommended that all parameters in the table except m and n should be found “from test.” Of course, this is not usually possible, especially if the transformer is already in service.

The temperature calculation equations are most concisely described in block diagram form, for details see Figure N.1: Block Diagram of Top Oil and Hot Spot Temperature Calculation Method (Inputs: per unit load and Ambient Temperature.) and Figure N.2: Block Diagram of Top Oil and Hot Spot Temperature Calculation Method (Inputs: per unit load and Top Oil Temperature.).

The two situations are

1 Top Oil temperature not sensed. For this case, the Top Oil temperature is calculated as a rise above the Ambient temperature, and the Hot Spot temperature as a rise above Top Oil temperature.
2 Top Oil temperature is sensed (an electrical analog input to the relay). For this case, the Hot Spot temperature is calculated as a rise above the measured Top Oil temperature.

Those parameters not already defined for the equations are as follows:

$\Delta\theta_{H,U}$	ultimate hot spot rise over top oil, in °C
$\Delta\theta_{H}$	time-varying hot spot rise over top oil, in °C
$\Delta\theta_{TO,U}$	ultimate top oil rise over ambient, in °C
$\Delta\theta_{TO}$	time-varying top oil rise over ambient, in °C
θ_{A}	ambient temperature, in °C

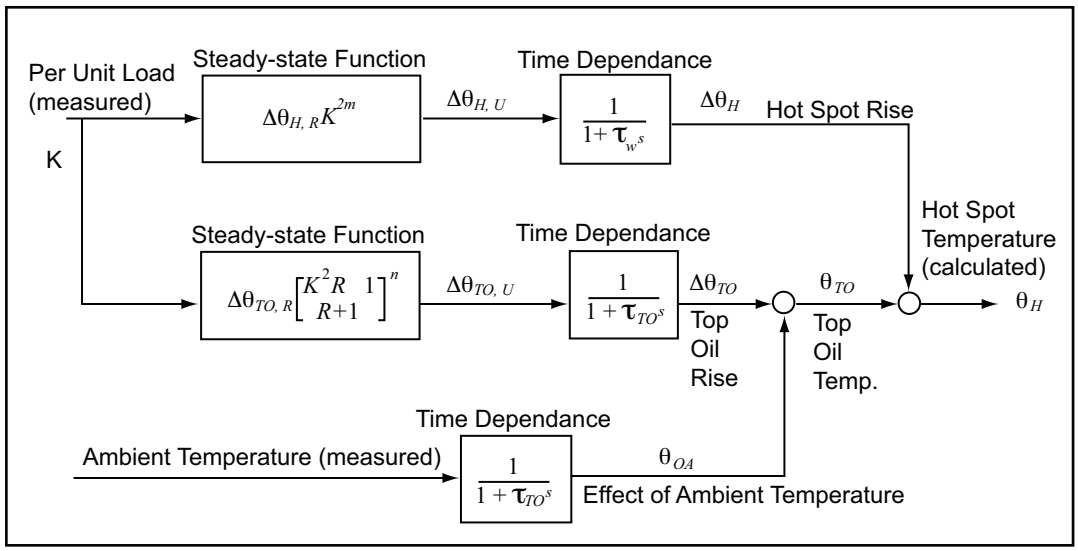


Figure N.1: Block Diagram of Top Oil and Hot Spot Temperature Calculation Method

Inputs: per unit load and Ambient Temperature.

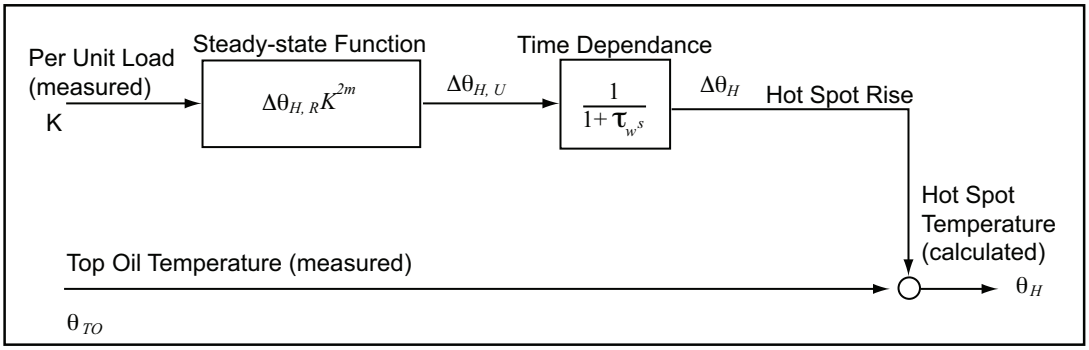


Figure N.2: Block Diagram of Top Oil and Hot Spot Temperature Calculation Method

Inputs: per unit load and Top Oil Temperature.

Appendix O Temperature Probe Connections

Example 1

Using one top oil probe and one ambient temperature probe with one T-PRO A, both powered from the T-PRO A.

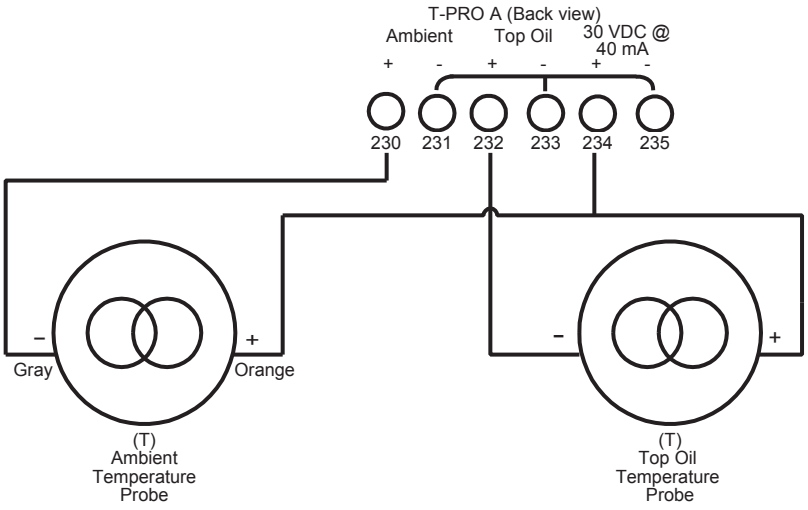


Figure O.1: T-PRO A (Back view)

Example 2

Using two top oil probes powered by two T-PRO relays (B and C) and one ambient temperature probe powered by T-PRO C.

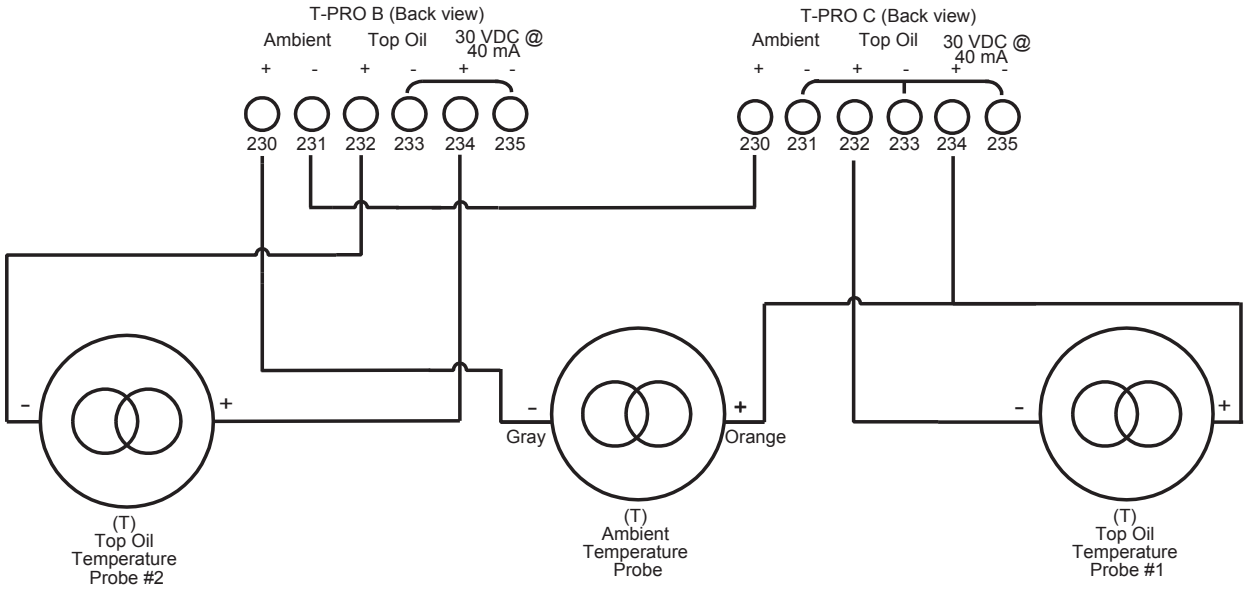
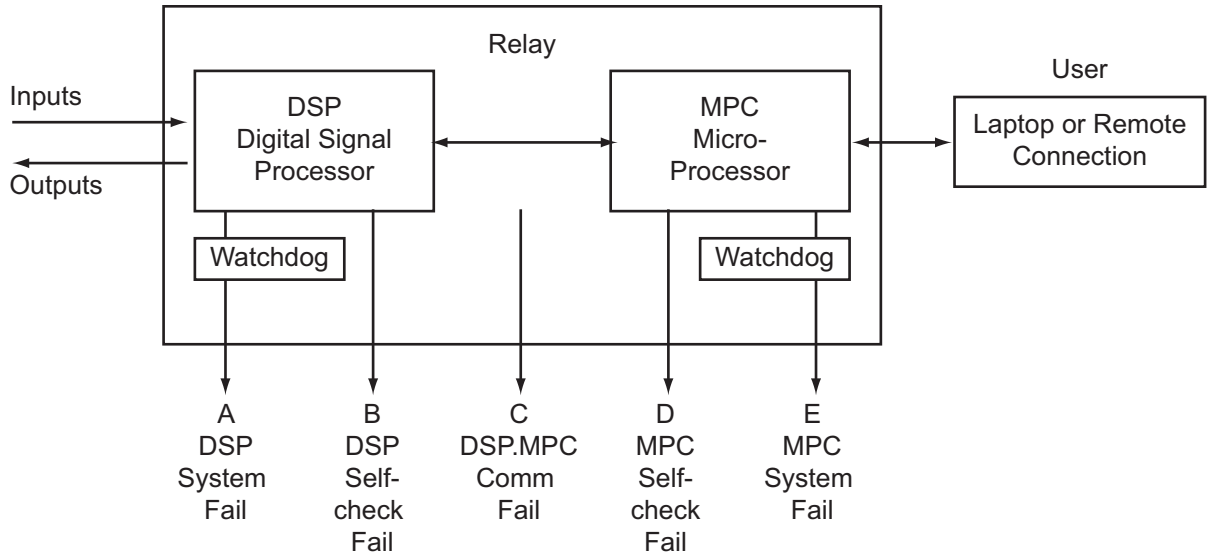


Figure O.2: T-PRO B (Back view) and T-PRO C (Back view)

Appendix P Failure Modes



P.1 Actions

A - DSP System Failure

The Relay Functional LED changes from green to off. The Master Relay is de-energized. Two of its contacts open, disconnecting power to the other auxiliary relays. A separate contact labeled “Relay Inoperative” on the rear panel closes to activate a remote alarm.

The watch-dog repeatedly attempts to re-start the DSP for diagnostic purposes. The Relay Functional LED stays off and the relays remain de-energized, even for a successful re-start. Only a power-down/power-up cycle will reset the LED to green and re-energize the relays.

B – DSP Self-Check Fail

The Self Check Fail output can be assigned and used in ProLogic statements and the Output Matrix.

There are two possibilities for DSP Self Check Fail, either Alarm or Block. Both are related to the dc offset on a channel which should not occur with proper calibration. Alarm just drives the optional output contact but Block causes the Relay Functional LED to go out and the relay to be unable to drive any output contact (as in the first and last paragraphs of section A - DSP System Failure above).

C – DSP- Micro Processor (MPC) Comm Failure

D - MPC Self-Check Fail

The Service Required LED changes from off to red.

E – MPC System Fail

The Test Mode LED changes from off to red until the MPC has rebooted. The watchdog will continue to attempt to re-start the MPC several times. If the MPC reboots but can not return to normal operation, the Service Required LED changes from off to red.

Appendix Q IEC61850 Implementation

Protocol Implementation Conformance Statement (PICS)

Introduction

This specification is the Protocol Implementation Conformance Statement (PICS) and presents the ACSI conformance statements as defined in Annex A of Part 7-2 of the IEC 61850 standard specifications.

ACSI basic conformance statement

The basic conformance statement shall be as defined in Table Q.1: Basic Conformance Statement.

Table Q.1: Basic Conformance Statement

		Server/ Publisher	Remarks
Client -Server Roles			
B11	**Server** Side (of TWO-PARTY-APPLICATION-ASSOCIATION)	c1	YES
B12	**Client** Side (of TWO-PARTY-APPLICATION-ASSOCIATION)		NO
SCSMs supported			
B21	**SCSM**:IEC 61850-8-1 used		YES
B22	**SCSM**:IEC 61850-9-1 used		NO
B23	**SCSM**:IEC 61850-9-2 used		NO
B24	**SCSM**: other		NO
Generic Substation event Model(GSE)			
B31	**Publisher** side	O	YES
B32	**Subscriber** Side		YES
Transmission of Sampled value model (SVC)			
B41	**Publisher** side	O	NO
B42	**Subscriber** side	-	NO

c1 - Shall be 'M' if support for **LOGICAL-DEVICE** model has been declared
O - Optional
M - Mandatory

ACSI models conformance statement

The ASCI models conformance statement shall be as defined in Table Q.2: ACSI models Conformance Statement.

Table Q.2: ACSI models Conformance Statement

		Server/ Publisher	Remarks
If **Server** side (B11) supported			
M1	Logical Device	c2	YES
M2	Logical Node	c3	YES
M3	Data	c4	YES
M4	Data Set	c5	YES
M5	Substitution	O	YES
M6	Setting group control	O	YES
Reporting			
M7	Buffered report control	O	YES
M7-1	Sequence – number		YES
M7-2	Report-time-stamp		YES
M7-3	Reason-for-inclusion		YES
M7-4	Data-set-name		YES
M7-5	Data-reference		YES
M7-6	Buffer-overflow		YES
M7-7	Entry id		YES
M7-8	Buf Tm		YES
M7-9	IntgPd		YES
M7-10	GI		YES
M8	Unbuffered report control	O	YES
M8-1	Sequence – number		YES
M8-2	Report-time-stamp		YES
M8-3	Reason-for-inclusion		YES
M8-4	Data-set-name		YES
M8-5	Data-reference		YES
M8-6	IntgPd		YES
M8-7	GI		YES
M9	Log control	O	NO

M9-1	IntgPd		NO
M10	Log	O	NO
M11	Control	M	YES
If **GSE** (B31/B32) is supported			
	GOOSE	O	YES
M12-1	EntryID		
M12-2	DataRefInc		
M13	GSSE	O	NO
If **SVC** (B41/B42) is supported			
M14	Multicast SVC	O	NO
M15	Unicast SVC	O	NO
M16	Time	M	YES
M17	File Transfer	O	YES
c2 – shall be 'M' if support for LOGICAL-NODE model has been declared c3 – shall be 'M' if support for DATA model has been declared c4 – shall be 'M' if support DATA-SET, Substitution, Report, Log Control, or Time model has been declared c5 – shall be 'M' if support for Report , GSE, or SV model has been declared M - Mandatory			

ACSI service conformance statement

The ASCI service conformance statement shall be as defined in Table Q.3: ACSI service Conformance Statement.

Table Q.3: ACSI service Conformance Statement

	Services	AA: TP/MC	Server/ Publisher	Remarks
Server (Clause 6)				
S1	ServerDirectory	TP	M	YES

Table Q.4: Application association (Clause 7)				
S2	Associate		M	YES
S3	Abort		M	YES
S4	Release		M	YES

Table Q.5: Logical device (Clause 8)				
S5	Logical Device Directory	TP	M	YES

Table Q.6: Logical Node (Clause 9)				
S6	LogicalNodeDirectory	TP	M	YES
S7	GetAllDataValues	TP	M	YES

Table Q.7: Data (Clause 10)				
S8	GetDataValues	TP	M	YES
S9	SetDataValues	TP	O	NO
S10	GetDataDirectory	TP	M	YES
S11	GetDataDefinition	TP	M	YES

Table Q.8: Data Set(Clause 11)				
S12	GetDataSetValues	TP	M	YES
S13	SetDataSetValues	TP	O	NO
S14	CreateDataSet	TP	O	NO
S15	DeleteDataSet	TP	O	NO
S16	GetDataSetDirectory	TP	O	YES

Table Q.9: Substitution (Clause 12)				
S17	SetDataValues	TP	M	YES

Table Q.10: Setting group control (Clause 13)				
S18	SelectActive SG	TP	O	YES
S19	SelectEdit SG	TP	O	NO
S20	SetSGvalues	TP	O	NO
S21	ConfirmEditSGvalues	TP	O	NO
S22	GetSGvalues	TP	O	YES
S23	GetSGCBvalues	TP	O	YES

Table Q.11: Reporting (Clause 14)				
Buffered report control block(BRCB)				
S24	Report	TP	c6	YES
S24-1	Data-change(dchg)			YES
S24-2	qchg-change(qchg)			NO
S24-3	Data-update(dupd)			NO
S25	GetBRCBValues	TP	c6	YES
S26	SetBRCBValues	TP	c6	YES
Unbuffered report control block(URCB)				
S27	Report	TP	c6	YES
S27-1	Data-change(dchg)			YES
S27-2	qchg-change(qchg)			NO
S27-3	Data-update(dupd)			NO
S28	GetURCBValues	TP	c6	YES
S29	SetURCBValues	TP	c6	YES
c6 – shall declare support for at least one(BRCB or URCB)				

Table Q.12: Logging(clause 14)				
Log Control block				
S30	GetLCBValues	TP	M	NO
S31	SetLCBValues	TP	M	NO
Log				
S32	QueryLogByTime	TP	M	NO
S33	QueryLogAfter	TP	M	NO
S34	GetLogStatusValues	TP	M	NO
c7- shall declare support for at least one(query log by time or Query LogAfter)				

Table Q.13: Generic Substation event model(GSE) (14.3.5.3.4)				
GOOSE – CONTROL - BLOCK				
S35	SendGOOSEMessage	MC	c8	YES
S36	GetGOReference	TP	c9	
S37	GetGOOSEElementNum-ber	TP	c9	
S38	GetGoCBValues	TP	O	YES
S39	SetGoCBValues	TP	O	NO
GSSE – CONTROL - BLOCK				
S40	SendGSSEMessage	MC	C8	NO
S41	GetGsReference	TP	C9	NO
S42	GetGSSEElementNumber	TP	C9	NO
S43	GetGsCBValues	TP	O	NO
S44	SetGsCBValues	TP	O	NO
c8- shall declare support for at least one(Send GOOSE Message or Send GSSE Message) c9- shall declare support if TP association is available				

Table Q.14: Transmission of sampled value model(SVC) (Clause 16)				
Multicast SVC				
S45	SendMSVMessage	MC	C10	NO
S46	GetMSVCBValues	TP	O	NO
S47	SetMSVCBValues	TP	O	NO
Unicast SVC				
S48	SendUSVMessage	TP	C10	NO
S49	GetUSVCBValues	TP	O	NO
S50	SetUSVCBValues	TP	O	NO
C10- shall declare support for at least one(Send MSV Message or Send USV Message)				

Table Q.15: control (17.5.1)				
S51	Select	TP	O	NO
S52	Select with value	TP	O	NO
S53	Cancel	TP	O	NO
S54	Operate	TP	M	YES
S55	Command-Termination	TP	O	NO
S56	Time Activated-Operate	TP	O	NO

Table Q.16: File Transfer (Clause 20)				
S57	GetFile	TP	M	YES
S58	SetFile	TP	O	NO
S59	DeleteFile	TP	O	YES
S60	GetFileAttributeValues	TP	M	YES

Table Q.17: Time(5.5)			
T1	Time resolution of Internal clock	10 msec	Nearest negative power of 2 in seconds
T2	TimeAccuracy of Internal clock	10 msec	T0
			T1
			T2
			T3
			T4
			T5
T3	Supported Time Stamp resolution	10 msec	Nearest value of 2**-n in seconds according to 5.5.3.7.3.3 (n corresponds to 7).

Data Mapping Specifications

T-PRO Logical Device

T-PRO logical device identifications

T-PRO 4000 has the following IEC 61850 logical devices defined in its ICD file:

- Measurements
- Protection
- Records
- System
- VirtualInputs
- FaultData

T-PRO logical nodes

Table Q.18: T-PRO Logical Devices defines the list of logical nodes (LN) for the T-PRO logical devices.

Note:

System logical nodes (group L) are not shown here

Table Q.18: T-PRO Logical Devices

LD Name	LN Name	LN Description	Protection Function	Comments
Measurements	HBFGGIO1	Measurement		I1 2nd and 5th harmonic metering data
Measurements	HBFGGIO2	Measurement		I2 2nd and 5th harmonic metering data
Measurements	HBFGGIO3	Measurement		I3 2nd and 5th harmonic metering data
Measurements	HBFGGIO4	Measurement		I4 2nd and 5th harmonic metering data
Measurements	HBFGGIO5	Measurement		I5 2nd and 5th harmonic metering data
Measurements	IMMXU1	Measurement		I1 3 phase metering data
Measurements	IMMXU2	Measurement		I2 3 phase metering data
Measurements	IMMXU3	Measurement		I3 3 phase metering data
Measurements	IMMXU4	Measurement		I4 3 phase metering data
Measurements	IMMXU5	Measurement		I5 3 phase metering data

Measurements	PwrVolMMXU6	Measurement		voltage 3 phase metering data Active power metering data Reactive power metering data Apparent power metering data Power factor metering data Total Active Power metering data Total Reactive Power metering data Total Apparent Power metering data Average Power factor metering data Frequency metering data
Measurements	IMSQI1	Measurement		I1 sequence metering data
Measurements	IMSQI2	Measurement		I2 sequence metering data
Measurements	IMSQI3	Measurement		I3 sequence metering data
Measurements	IMSQI4	Measurement		I4 sequence metering data
Measurements	IMSQI5	Measurement		I5 sequence metering data
Measurements	VoltMSQI6	Measurement		voltage sequence metering data
Protection	D24DEFPVPH1	Volts per Hz	D24DEF-1	24DEF-1 Trip
Protection	D24DEFPVPH2	Volts per Hz	D24DEF-2	24DEF-2 Trip
Protection	D24InvPVPH3	Volts per Hz	D24INV	24INV Alarm and Trip
Protection	D27_1PTUV1	Undervoltage	D27-1	27-1 Trip
Protection	D27_2PTUV2	Undervoltage	D27-2	27-2 Trip
Protection	D49PTTR1	Thermal overload	D49-1	49-1 Operates
Protection	D49PTTR2	Thermal overload	D49-2	49-2 Operates
Protection	D49PTTR3	Thermal overload	D49-3	49-3 Operates
Protection	D49PTTR4	Thermal overload	D49-4	49-4 Operates
Protection	D49PTTR5	Thermal overload	D49-5	49-5 Operates
Protection	D49PTTR6	Thermal overload	D49-6	49-6 Operates
Protection	D49PTTR7	Thermal overload	D49-7	49-7 Operates
Protection	D49PTTR8	Thermal overload	D49-8	49-8 Operates
Protection	D49PTTR9	Thermal overload	D49-9	49-9 Operates
Protection	D49PTTR10	Thermal overload	D49-10	49-10 Operates
Protection	D49PTTR11	Thermal overload	D49-11	49-11 Operates
Protection	D49PTTR12	Thermal overload	D49-12	49- 12Operates
Protection	D50BFRBRF1	Breaker failure	Input 1 D50BF-1	Input 1 50BF-1 Trip

Protection	D50BFRBRF2	Breaker failure	Input 1 D50BF-2	Input 1 50BF-2 Trip
Protection	D50BFRBRF3	Breaker failure	Input 2 D50BF-1	Input 2 50BF-1 Trip
Protection	D50BFRBRF4	Breaker failure	Input 2 D50BF-2	Input 2 50BF-2 Trip
Protection	D50BFRBRF5	Breaker failure	Input 3 D50BF-1	Input 3 50BF-1 Trip
Protection	D50BFRBRF6	Breaker failure	Input 3 D50BF-2	Input 3 50BF-2 Trip
Protection	D50BFRBRF7	Breaker failure	Input 4 D50BF-1	Input 4 50BF-1 Trip
Protection	D50BFRBRF8	Breaker failure	Input 4 D50BF-2	Input 4 50BF-2 Trip
Protection	D50BFRBRF9	Breaker failure	Input 5 D50BF-1	Input 5 50BF-1 Trip
Protection	D50BFRBRF10	Breaker failure	Input 5 D50BF-2	Input 5 50BF-2 Trip
Protection	CBFIHRBRF11	Breaker failure	BFI HV	Breaker Failure Initiation HV
Protection	CBFILRBRF12	Breaker failure	BFI LV	Breaker Failure Initiation LV
Protection	CBFITRBRF13	Breaker failure	BFI TV	Breaker Failure Initiation TV
Protection	D50HVPIOC1	Instantaneous over-current	D50-HV	50-HV Trip
Protection	D50LVPIOC2	Instantaneous over-current	D50-LV	50-LV Trip
Protection	D50TVPIOC3	Instantaneous over-current	D50-TV	50-TV Trip
Protection	D50NHVPIOC4	Instantaneous over-current	D50N-HV	50N-HV Alarm and Trip
Protection	D50NLVPIOC5	Instantaneous over-current	D50N-LV	50N-LV Alarm and Trip
Protection	D50NTVPIOC6	Instantaneous over-current	D50N-TV	50N-TV Alarm and Trip
Protection	D51HVPTOC1	Time overcurrent	D51-HV	51-HV Trip
Protection	D51LVPTOC2	Time overcurrent	D51-LV	51-LV Trip
Protection	D51TVPTOC3	Time overcurrent	D51-TV	51-TV Trip
Protection	D51NHVPTOC4	Time overcurrent	D51N-HV	51N-HV Alarm and Trip
Protection	D51NLVPTOC5	Time overcurrent	D51N-LV	51N-LV Alarm and Trip
Protection	D51NTVPTOC6	Time overcurrent	D51N-TV	51N-TV Alarm and Trip
Protection	D67PTOC7	Time overcurrent	D67	67 Alarm and Trip
Protection	D67NPTOC8	Time overcurrent	D67N	67N Alarm and Trip
Protection	D59NPTOV1	Overvoltage	D59N	59N Alarm and Trip

Protection	D59_1PTOV2	Overvoltage	D59-1	59-1 Trip
Protection	D59_2PTOV3	Overvoltage	D59-2	59-2 Trip
Protection	D81PFRC1	Rate of change of frequency	D81ROC -1	81 ROC-1 Trip
Protection	D81PFRC2	Rate of change of frequency	D81ROC -2	81 ROC -2 Trip
Protection	D81PFRC3	Rate of change of frequency	D81ROC -3	81 ROC -3 Trip
Protection	D81PFRC4	Rate of change of frequency	D81ROC -4	81 ROC -3 Trip
Protection	D81PTOF1	Overfrequency	D81 O/F -1	81 O/F-1 Trip
Protection	D81PTOF2	Overfrequency	D81 O/F -2	81 O/F-2 Trip
Protection	D81PTOF3	Overfrequency	D81 O/F -3	81 O/F-3 Trip
Protection	D81PTOF4	Overfrequency	D81 O/F -4	81 O/F-4 Trip
Protection	D81PTUF1	Underfrequency	D81 U/F -1	81 U/F-1 Trip
Protection	D81PTUF2	Underfrequency	D81 U/F -2	81 U/F-2 Trip
Protection	D81PTUF3	Underfrequency	D81 U/F -3	81 U/F-3 Trip
Protection	D81PTUF4	Underfrequency	D81 U/F -4	81 U/F-4 Trip
Protection	D87TPDIF1	Differential	D87T	87 Trip
Protection	D87NHVPDIF2	Differential	D87N-HV	87N-HV Trip
Protection	D87NLVPDIF3	Differential	D87N-LV	87N-LV Trip
Protection	D87NTVPDIF4	Differential	D87N-TV	87N-TV Trip
Protection	PTFuseGGIO1	Generic process I/O		PT Fuse Failure operation
System	EIGGIO1	Generic process I/O		External Inputs 1 to 20
System	OCGGIO2	Generic process I/O		Output Contacts 1 to 21
System	PLGGIO3	Generic process I/O		ProLogic functions 1 to 24
System	XFMRGGIO4	Generic process I/O		TOEWS Alarms and Trip THD Alarm Ambient, Top Oil Alarms Through Fault Alarm
System	SGGGIO5	Generic process I/O		Active setting group
System	VIGGIO6	Generic process I/O		Virtual Inputs 1 to 30
System	LEDGGIO7	Generic process I/O		Target LED 1 to 11 Alarm LED Service required LED
System	SChAlmGGIO8	Generic process I/O		Self Check Fail Alarm
System	TSAlmGGIO9	Generic process I/O		Time Synchronization Alarm
VirtualInputs	SUBSCRGGIO1	Generic process I/O		External GOOSE Virtual Inputs

FaultData	D24DEFMMXU1	Measurement	D24DEF-1	24DEF-1 fault frequency
FaultData	D24DEFMMXU2	Measurement	D24DEF-2	24DEF-2 fault frequency
FaultData	D24InvMMXU3	Measurement	D24INV	24INV fault frequency
FaultData	D50NHVMMXU4	Measurement	D50N-HV	50N-HV fault currents
FaultData	D51NHVMMXU5	Measurement	D51N-HV	51N-HV fault currents
FaultData	D50NLVMMXU6	Measurement	D50N-LV	50N-LV fault currents
FaultData	D51NLVMMXU7	Measurement	D51N-LV	51N-LV fault currents
FaultData	D50NTVMMXU8	Measurement	D50N-TV	50N-TV fault currents
FaultData	D51NTVMMXU9	Measurement	D51N-TV	51N-TV fault currents
FaultData	D50HVMMXU10	Measurement	D50-HV	50-HV fault currents
FaultData	D51HVMMXU11	Measurement	D51-HV	51-HV fault currents
FaultData	D50LVMMXU12	Measurement	D50-LV	50-LV fault currents
FaultData	D51LVMMXU13	Measurement	D51-LV	51-LV fault currents
FaultData	D50TVMMXU14	Measurement	D50-TV	50-TV fault currents
FaultData	D51TVMMXU15	Measurement	D51-TV	51-TV fault currents
FaultData	D59_1MMXU16	Measurement	D59-1	59-1 fault voltages
FaultData	D59_2MMXU17	Measurement	D59-2	59-2 fault voltages
FaultData	D27_1MMXU18	Measurement	D27-1	27-1 fault voltages
FaultData	D27_2MMXU19	Measurement	D27-2	27-2 fault voltages
FaultData	D67MMXU20	Measurement	D67	67 fault voltages and currents
FaultData	D87MMXU21	Measurement	D87	87 operating and restraint fault currents
FaultData	D67NMMXU22	Measurement	D67N	67N fault voltages and currents
FaultData	D24DEFMSQI1	Sequence and imbalance	D24DEF-1	24DEF-1 fault sequence voltages
FaultData	D24DEFMSQI2	Sequence and imbalance	D24DEF-2	24DEF-1 fault sequence voltages
FaultData	D24InvMSQI3	Sequence and imbalance	D24INV	24INV fault sequence voltages
FaultData	D87NHVMMXN1	Non-phase-related measurement	D87N-HV	87N-HV operating and restraint fault currents
FaultData	D87NLVMMXN2	Non-phase-related measurement	D87N-LV	87N-LV operating and restraint fault currents
FaultData	D87NTVMMXN3	Non-phase-related measurement	D87N-TV	87N-TV operating and restraint fault currents

Logical node specifications

The following sections provide detailed information on the logical nodes of the T-PRO logical devices as defined in the previous section.

Note:

Common Logical Node information is not shown in the following sections. Only the data that are provided from the T-PRO application to the IEC 61850 sub-system are described.

HBFGGIO1

This section defines logical node data for the logical node HBFGGIO1 of the logical device Measurements.

Data Name	Description
HBFGGIO1MXAnIn1magf	I1 phase A 2nd harmonic magnitude
HBFGGIO1MXAnIn2magf	I1 phase B 2nd harmonic magnitude
HBFGGIO1MXAnIn3magf	I1 phase C 2nd harmonic magnitude
HBFGGIO1MXAnIn4magf	I1 phase A 5th harmonic magnitude
HBFGGIO1MXAnIn5magf	I1 phase B 5th harmonic magnitude
HBFGGIO1MXAnIn6magf	I1 phase C 5th harmonic magnitude

HBFGGIO2

This section defines logical node data for the logical node HBFGGIO2 of the logical device Measurements.

Data Name	Description
HBFGGIO2MXAnIn1magf	I2 phase A 2nd harmonic magnitude
HBFGGIO2MXAnIn2magf	I2 phase B 2nd harmonic magnitude
HBFGGIO2MXAnIn3magf	I2 phase C 2nd harmonic magnitude
HBFGGIO2MXAnIn4magf	I2 phase A 5th harmonic magnitude
HBFGGIO2MXAnIn5magf	I2 phase B 5th harmonic magnitude
HBFGGIO2MXAnIn6magf	I2 phase C 5th harmonic magnitude

HBFGGIO3

This section defines logical node data for the logical node HBFGGIO3 of the logical device Measurements.

Data Name	Description
HBFGGIO3MXAnIn1magf	I3 phase A 2nd harmonic magnitude
HBFGGIO3MXAnIn2magf	I3 phase B 2nd harmonic magnitude
HBFGGIO3MXAnIn3magf	I3 phase C 2nd harmonic magnitude
HBFGGIO3MXAnIn4magf	I3 phase A 5th harmonic magnitude
HBFGGIO3MXAnIn5magf	I3 phase B 5th harmonic magnitude
HBFGGIO3MXAnIn6magf	I3 phase C 5th harmonic magnitude

HBFGGIO4

This section defines logical node data for the logical node HBFGGIO4 of the logical device Measurements.

Data Name	Description
HBFGGIO4MXAnIn1magf	I4 phase A 2nd harmonic magnitude
HBFGGIO4MXAnIn2magf	I4 phase B 2nd harmonic magnitude
HBFGGIO4MXAnIn3magf	I4 phase C 2nd harmonic magnitude
HBFGGIO4MXAnIn4magf	I4 phase A 5th harmonic magnitude
HBFGGIO4MXAnIn5magf	I4 phase B 5th harmonic magnitude
HBFGGIO4MXAnIn6magf	I4 phase C 5th harmonic magnitude

HBFGGIO5

This section defines logical node data for the logical node HBFGGIO5 of the logical device Measurements.

Data Name	Description
HBFGGIO5MXAnIn1magf	I5 phase A 2nd harmonic magnitude
HBFGGIO5MXAnIn2magf	I5 phase B 2nd harmonic magnitude
HBFGGIO5MXAnIn3magf	I5 phase C 2nd harmonic magnitude
HBFGGIO5MXAnIn4magf	I5 phase A 5th harmonic magnitude
HBFGGIO5MXAnIn5magf	I5 phase B 5th harmonic magnitude
HBFGGIO5MXAnIn6magf	I5 phase C 5th harmonic magnitude

IMMXU1

This section defines logical node data for the logical node IMMXU1 of the logical device Measurements.

Data Name	Description
IMMXU1MXA$phsA$cValmagf	I1 phase A magnitude
IMMXU1MXA$phsA$cValangf	I1 phase A angle
IMMXU1MXA$phsB$cValmagf	I1 phase B magnitude
IMMXU1MXA$phsB$cValangf	I1 phase B angle
IMMXU1MXA$phsC$cValmagf	I1 phase C magnitude
IMMXU1MXA$phsC$cValangf	I1 phase C angle

IMMXU2

This section defines logical node data for the logical node IMMXU2 of the logical device Measurements.

Data Name	Description
IMMXU2MXA$phsA$cValmagf	I2 phase A magnitude
IMMXU2MXA$phsA$cValangf	I2 phase A angle
IMMXU2MXA$phsB$cValmagf	I2 phase B magnitude
IMMXU2MXA$phsB$cValangf	I2 phase B angle
IMMXU2MXA$phsC$cValmagf	I2 phase C magnitude
IMMXU2MXA$phsC$cValangf	I2 phase C angle

IMMXU3

This section defines logical node data for the logical node IMMXU3 of the logical device Measurements.

Data Name	Description
IMMXU3MXA$phsA$cValmagf	I3 phase A magnitude
IMMXU3MXA$phsA$cValangf	I3 phase A angle
IMMXU3MXA$phsB$cValmagf	I3 phase B magnitude
IMMXU3MXA$phsB$cValangf	I3 phase B angle
IMMXU3MXA$phsC$cValmagf	I3 phase C magnitude
IMMXU3MXA$phsC$cValangf	I3 phase C angle

IMMXU4

This section defines logical node data for the logical node IMMXU4 of the logical device Measurements.

Data Name	Description
IMMXU4MXA$phsA$cValmagf	I4 phase A magnitude
IMMXU4MXA$phsA$cValangf	I4 phase A angle
IMMXU4MXA$phsB$cValmagf	I4 phase B magnitude
IMMXU4MXA$phsB$cValangf	I4 phase B angle
IMMXU4MXA$phsC$cValmagf	I4 phase C magnitude
IMMXU4MXA$phsC$cValangf	I4 phase C angle

IMMXU5

This section defines logical node data for the logical node IMMXU5 of the logical device Measurements.

Data Name	Description
IMMXU5MXA$phsA$cValmagf	I5 phase A magnitude
IMMXU5MXA$phsA$cValangf	I5 phase A angle
IMMXU5MXA$phsB$cValmagf	I5 phase B magnitude
IMMXU5MXA$phsB$cValangf	I5 phase B angle
IMMXU5MXA$phsC$cValmagf	I5 phase C magnitude
IMMXU5MXA$phsC$cValangf	I5 phase C angle

IMSQI1

This section defines logical node data for the logical node IMSQI1 of the logical device Measurements.

Data Name	Description
IMSQI1MXSeqA$c1$cValmagf	I1 positive sequence current
IMSQI1MXSeqA$c2$cValmagf	I1 negative sequence current
IMSQI1MXSeqA$c3$cValmagf	I1 zero sequence current

IMSQI2

This section defines logical node data for the logical node IMSQI2 of the logical device Measurements.

Data Name	Description
IMSQI2MXSeqA$c1$cValmagf	I2 positive sequence current
IMSQI2MXSeqA$c2$cValmagf	I2 negative sequence current
IMSQI2MXSeqA$c3$cValmagf	I2 zero sequence current

IMSQI3

This section defines logical node data for the logical node IMSQI3 of the logical device Measurements.

Data Name	Description
IMSQI3MXSeqA$c1$cValmagf	I3 positive sequence current
IMSQI3MXSeqA$c2$cValmagf	I3 negative sequence current
IMSQI3MXSeqA$c3$cValmagf	I3 zero sequence current

IMSQI4

This section defines logical node data for the logical node IMSQI4 of the logical device Measurements.

Data Name	Description
IMSQI4MXSeqA$c1$cValmagf	I4 positive sequence current
IMSQI4MXSeqA$c2$cValmagf	I4 negative sequence current
IMSQI4MXSeqA$c3$cValmagf	I4 zero sequence current

IMSQI5

This section defines logical node data for the logical node IMSQI5 of the logical device Measurements.

Data Name	Description
IMSQI5MXSeqA$c1$cValmagf	I5 positive sequence current
IMSQI5MXSeqA$c2$cValmagf	I5 negative sequence current
IMSQI5MXSeqA$c3$cValmagf	I5 zero sequence current

VoltQI6

This section defines logical node data for the logical node VoltMSQI6of the logical device Measurements.

Data Name	Description
VoltMSQI6MXSeqV$c1$cValmagf	positive sequence voltage
VoltMSQI6MXSeqV$c2$cValmagf	negative sequence voltage
VoltMSQI6MXSeqV$c3$cValmagf	zero sequence voltage

PwrVolMMXU6

This section defines logical node data for the logical node PwrVolMMXU6 of the logical device Measurements.

Data Name	Description
PwrVolMMXU6MXPhV$phsA$cValmagf	Voltage phase A magnitude
PwrVolMMXU6MXPhV$phsA$cValangf	Voltage phase A angle
PwrVolMMXU6MXPhV$phsB$cValmagf	Voltage phase B magnitude
PwrVolMMXU6MXPhV$phsB$cValangf	Voltage phase B angle
PwrVolMMXU6MXPhV$phsC$cValmagf	Voltage phase C magnitude
PwrVolMMXU6MXPhV$phsC$cValangf	Voltage phase C angle
PwrVolMMXU6MXW$phsA$cValmagf	Phase A active power
PwrVolMMXU6MXW$phsB$cValmagf	Phase B active power
PwrVolMMXU6MXW$phsC$cValmagf	Phase C active power
PwrVolMMXU6MXVAr$phsA$cValmagf	Phase A reactive power
PwrVolMMXU6MXVAr$phsB$cValmagf	Phase B reactive power
PwrVolMMXU6MXVAr$phsC$cValmagf	Phase C reactive power
PwrVolMMXU6MXVA$phsA$cValmagf	Phase A apparent power
PwrVolMMXU6MXVA$phsB$cValmagf	Phase B apparent power
PwrVolMMXU6MXVA$phsC$cValmagf	Phase C apparent power
PwrVolMMXU6MXPF$phsA$cValmagf	Phase A power factor
PwrVolMMXU6MXPF$phsB$cValmagf	Phase B power factor
PwrVolMMXU6MXPF$phsC$cValmagf	Phase C power factor
PwrVolMMXU6MXTotWmagf	Total active power
PwrVolMMXU6MXTotVArmagf	Total reactive power
PwrVolMMXU6MXTotVAmagf	Total apparent power
PwrVolMMXU6MXTotPFmagf	Average power factor
PwrVolMMXU6MXHzmagf	Frequency

D24DEFPVPH1

This section defines logical node data for the logical node D24DEFPVPH1of the logical device Protection.

Data Name	Description
D24DEFPVPH1STStr$general	24DEF-1 Trip
D24DEFPVPH1STStr$dirGeneral	24DEF-1 Direction (set to “unknown”)
D24DEFPVPH1STOp$general	24DEF-1 Trip

D24DEFPVPH2

This section defines logical node data for the logical node D24DEFPVPH2of the logical device Protection.

Data Name	Description
D24DEFPVPH2STStr$general	24DEF-2 Trip
D24DEFPVPH2STStr$dirGeneral	24DEF-2 Direction (set to “unknown”)
D24DEFPVPH2STOp$general	24DEF-2 Trip

D24InvPVPH3

This section defines logical node data for the logical node D24InvVPH3of the logical device Protection.

Data Name	Description
D24InvPVPH3STStr$general	24INV Alarm
D24InvPVPH3STStr$dirGeneral	24INV Direction (set to “unknown”)
D24InvPVPH3STOp$general	24INV Trip

D27_1PTUV1

This section defines logical node data for the logical node D27_1PTUV1of the logical device Protection.

Data Name	Description
D27_1PTUV1STStr$general	27-1 Trip
D27_1PTUV1STStr$dirGeneral	27-1 Direction (set to “unknown”)
D27_1PTUV1STOp$general	27-1 Trip
D27_1PTUV1STOp$phsA	27-1 Trip phase A
D27_1PTUV1STOp$phsB	27-1 Trip phase B
D27_1PTUV1STOp$phsC	27-1 Trip phase C

D27_2PTUV2

This section defines logical node data for the logical node D27_2PTUV2of the logical device Protection.

Data Name	Description
D27_2PTUV2STStr$general	27-2 Trip
D27_2PTUV2STStr$dirGeneral	27-2 Direction (set to “unknown”)
D27_2PTUV2STOp$general	27-2 Trip
D27_2PTUV2STOp$phsA	27-2 Trip phase A
D27_2PTUV2STOp$phsB	27-2 Trip phase B
D27_2PTUV2STOp$phsC	27-2 Trip phase C

D49PTTR1

This section defines logical node data for the logical node D49PTTR1of the logical device Protection.

Data Name	Description
D49PTTR1STOp$general	49-1 Operates

D49PTTR2

This section defines logical node data for the logical node D49PTTR2of the logical device Protection.

Data Name	Description
D49PTTR2STOp$general	49-2 Operates

D49PTTR3

This section defines logical node data for the logical node D49PTTR3of the logical device Protection.

Data Name	Description
D49PTTR3STOp$general	49-3 Operates

D49PTTR4

This section defines logical node data for the logical node D49PTTR4of the logical device Protection.

Data Name	Description
D49PTTR4STOp$general	49-4 Operates

D49PTTR5

This section defines logical node data for the logical node D49PTTR5 of the logical device Protection.

Data Name	Description
D49PTTR5STOp$general	49-5 Operates

D49PTTR6

This section defines logical node data for the logical node D49PTTR6of the logical device Protection.

Data Name	Description
D49PTTR6STOp$general	49-6 Operates

D49PTTR7

This section defines logical node data for the logical node D49PTTR7of the logical device Protection.

Data Name	Description
D49PTTR7STOp$general	49-7 Operates

D49PTTR8

This section defines logical node data for the logical node D49PTTR8of the logical device Protection.

Data Name	Description
D49PTTR8STOp$general	49-8 Operates

D49PTTR9

This section defines logical node data for the logical node D49PTTR9of the logical device Protection.

Data Name	Description
D49PTTR9STOp$general	49-9 Operates

D49PTTR10

This section defines logical node data for the logical node D49PTTR10of the logical device Protection.

Data Name	Description
D49PTTR10STOp$general	49-10 Operates

D49PTTR11

This section defines logical node data for the logical node D49PTTR11 of the logical device Protection.

Data Name	Description
D49PTTR11STOp$general	49-11 Operates

D49PTTR12

This section defines logical node data for the logical node D49PTTR12of the logical device Protection.

Data Name	Description
D49PTTR12STOp$general	49-12 Operates

D50BFRBRF1

This section defines logical node data for the logical node D50BFRBRF1of the logical device Protection.

Data Name	Description
D50BFRBRF1STOpEx$general	50BF Input 1 Trip 1

D50BFRBRF2

This section defines logical node data for the logical node D50BFRBRF2 of the logical device Protection.

Data Name	Description
D50BFRBRF2STOpEx$general	50BF Input 1 Trip 2

D50BFRBRF3

This section defines logical node data for the logical node D50BFRBRF3 of the logical device Protection.

Data Name	Description
D50BFRBRF3STOpEx$general	50BF Input 2 Trip 1

D50BFRBRF4

This section defines logical node data for the logical node D50BFRBRF4 of the logical device Protection.

Data Name	Description
D50BFRBRF4STOpEx$general	50BF Input 2 Trip 2

D50BFRBRF5

This section defines logical node data for the logical node D50BFRBRF5 of the logical device Protection.

Data Name	Description
D50BFRBRF5STOpEx$general	50BF Input 3 Trip 1

D50BFRBRF6

This section defines logical node data for the logical node D50BFRBRF6 of the logical device Protection.

Data Name	Description
D50BFRBRF6STOpEx$general	50BF Input 3 Trip 2

D50BFRBRF7

This section defines logical node data for the logical node D50BFRBRF7 of the logical device Protection.

Data Name	Description
D50BFRBRF7STOpEx$general	50BF Input 4 Trip 1

D50BFRBRF8

This section defines logical node data for the logical node D50BFRBRF8 of the logical device Protection.

Data Name	Description
D50BFRBRF8STOpEx$general	50BF Input 4 Trip 2

D50BFRBRF9

This section defines logical node data for the logical node D50BFRBRF9 of the logical device Protection.

Data Name	Description
D50BFRBRF9STOpEx$general	50BF Input 5 Trip 1

D50BFRBRF10

This section defines logical node data for the logical node D50BFRBRF10 of the logical device Protection.

Data Name	Description
D50BFRBRF10STOpEx$general	50BF Input 5 Trip 2

CBFIHRBRF11

This section defines logical node data for the logical node CBFIHRBRF11of the logical device Protection.

Data Name	Description
CBFIHRBRF11STOpEx$general	Breaker Failure Initiation HV

CBFIHRBRF12

This section defines logical node data for the logical node CBFILRBRF12 of the logical device Protection.

Data Name	Description
CBFILRBRF12STOpEx$general	Breaker Failure Initiation LV

CBIFITRBRF13

This section defines logical node data for the logical node CBFITRBRF13 of the logical device Protection.

Data Name	Description
CBFITRBRF13STOpEx$general	Breaker Failure Initiation TV

D50HVPIOC1

This section defines logical node data for the logical node D50HVPIOC1of the logical device Protection.

Data Name	Description
D50HVPIOC1STOp$general	50-HV Trip

D50LVPIOC2

This section defines logical node data for the logical node D50LVPIOC2 of the logical device Protection.

Data Name	Description
D50LVPIOC2STOp$general	50-LV Trip

D50TVPIOC3

This section defines logical node data for the logical node D50TVPIOC3 of the logical device Protection.

Data Name	Description
D50TVPIOC3STOp$general	50-TV Trip

D50NHVPIOC4

This section defines logical node data for the logical node D50NHVPIOC4of the logical device Protection.

Data Name	Description
D50NHVPIOC4STOp$general	50N-HV Trip

D50NLVPIOC5

This section defines logical node data for the logical node D50NLVPIOC5of the logical device Protection.

Data Name	Description
D50NLVPIOC5STOp$general	50N-LV Trip

D50NTVPIOC6

This section defines logical node data for the logical node D50NTVPIOC6of the logical device Protection.

Data Name	Description
D50NTVPIOC6STOp$general	50N-TV Trip

D51HVPTOC1

This section defines logical node data for the logical node D51HVPTOC1of the logical device Protection.

Data Name	Description
D51HVPTOC1STStr$general	51-HV Alarm
D51HVPTOC1STStr$dirGeneral	51-HV Direction (set to “unknown”)
D51HVPTOC1STOp$general	51-HV Trip

D51LVPTOC2

This section defines logical node data for the logical node D51LVPTOC2 of the logical device Protection.

Data Name	Description
D51LVPTOC2STStr$general	51-LV Alarm
D51LVPTOC2STStr$dirGeneral	51-LV Direction (set to “unknown”)
D51LVPTOC2STOp$general	51-LV Trip

D51TVPTOC3

This section defines logical node data for the logical node D51TVPTOC3 of the logical device Protection.

Data Name	Description
D51TVPTOC3STStr$general	51-TV Alarm
D51TVPTOC3STStr$dirGeneral	51-TV Direction (set to “unknown”)
D51TVPTOC3STOp$general	51-TV Trip

D51NHVPTOC4

This section defines logical node data for the logical node D51NHVPTOC4of the logical device Protection.

Data Name	Description
D51NHVPTOC4STStr$general	51N-HV Alarm
D51NHVPTOC4STStr$dirGeneral	51N-HV Direction (set to “unknown”)
D51NHVPTOC4STOp$general	51N-HV Trip

D51NLVPTOC5

This section defines logical node data for the logical node D51NLVPTOC5of the logical device Protection.

Data Name	Description
D51NLVPTOC5STStr$general	51N-LV Alarm
D51NLVPTOC5STStr$dirGeneral	51N-LV Direction (set to “unknown”)
D51NLVPTOC5STOp$general	51N-LV Trip

D51NTVPTOC6

This section defines logical node data for the logical node D51NTVPTOC6of the logical device Protection.

Data Name	Description
D51NTVPTOC6STStr$general	51N-TV Alarm
D51NTVPTOC6STStr$dirGeneral	51N-TV Direction (set to “unknown”)
D51NTVPTOC6STOp$general	51N-TV Trip

D67PTOC7

This section defines logical node data for the logical node D67PTOC7of the logical device Protection.

Data Name	Description
D67PTOC7STStr$general	67 Alarm
D67PTOC7STStr$dirGeneral	67 Direction
D67PTOC7STOp$general	67 Trip

D67NPTOC8

This section defines logical node data for the logical node D67NPTOC8of the logical device Protection.

Data Name	Description
D67NPTOC8STStr$general	67N Alarm
D67NPTOC8STStr$dirGeneral	67N Direction
D67NPTOC8STOp$general	67N Trip

D59NPTOV1

This section defines logical node data for the logical node D59NPTOV1of the logical device Protection.

Data Name	Description
D59NPTOV1STStr$general	59N Alarm
D59NPTOV1STStr$dirGeneral	59N Direction (set to “unknown”)
D59NPTOV1STOp$general	59N Trip

D59_1PTOV2

This section defines logical node data for the logical node D59_1PTOV2of the logical device Protection.

Data Name	Description
D59_1PTOV2STStr$general	59-1 Trip
D59_1PTOV2STStr$dirGeneral	59-1 Direction (set to “unknown”)
D59_1PTOV2STOp$general	59-1 Trip
D59_1PTOV2STOp$phsA	59-1 Trip phase A
D59_1PTOV2STOp$phsB	59-1 Trip phase B
D59_1PTOV2STOp$phsC	59-1 Trip phase C

D59_2PTOV3

This section defines logical node data for the logical node D59_2PTOV3of the logical device Protection.

Data Name	Description
D59_2PTOV3STStr$general	59-2 Trip
D59_2PTOV3STStr$dirGeneral	59-2 Direction (set to “unknown”)
D59_2PTOV3STOp$general	59-2 Trip
D59_2PTOV3STOp$phsA	59-2 Trip phase A
D59_2PTOV3STOp$phsB	59-2 Trip phase B
D59_2PTOV3STOp$phsC	59-2 Trip phase C

D**81PFRC1**

This section defines logical node data for the logical node D81PFRC1of the logical device Protection.

Data Name	Description
D81PFRC1STStr$general	81-1 ROC Trip
D81PFRC1STStr$dirGeneral	81-1 ROC Direction (set to “unknown”)
D81PFRC1STOp$general	81-1 ROC Trip

D81PFRC2

This section defines logical node data for the logical node D81PFRC2 of the logical device Protection.

Data Name	Description
D81PFRC2STStr$general	81-2 ROC Trip
D81PFRC2STStr$dirGeneral	81-2 ROC Direction (set to “unknown”)
D81PFRC1STOp$general	81-2 ROC Trip

D81PFRC3

This section defines logical node data for the logical node D81PFRC3 of the logical device Protection.

Data Name	Description
D81PFRC3STStr$general	81-3 ROC Trip
D81PFRC3STStr$dirGeneral	81-3 ROC Direction (set to “unknown”)
D81PFRC3STOp$general	81-3 ROC Trip

D81PFRC4

This section defines logical node data for the logical node D81PFRC4 of the logical device Protection.

Data Name	Description
D81PFRC4STStr$general	81-4 ROC Trip
D81PFRC4STStr$dirGeneral	81-4 ROC Direction (set to “unknown”)
D81PFRC1STOp$general	81-4 ROC Trip

D81PTOF1

This section defines logical node data for the logical node D81PTOF1of the logical device Protection.

Data Name	Description
D81PTOF1STStr$general	81-1 O/F Trip
D81PTOF1STStr$dirGeneral	81-1 O/F Direction (set to “unknown”)
D81PTOF1STOp$general	81-1 O/F Trip

D81PTOF2

This section defines logical node data for the logical node D81PTOF2of the logical device Protection.

Data Name	Description
D81PTOF2STStr$general	81-2 O/F Trip
D81PTOF2STStr$dirGeneral	81-2 O/F Direction (set to “unknown”)
D81PTOF2STOp$general	81-2 O/F Trip

D81PTOF3

This section defines logical node data for the logical node D81PTOF3of the logical device Protection.

Data Name	Description
D81PTOF3STStr$general	81-3 O/F Trip
D81PTOF3STStr$dirGeneral	81-3 O/F Direction (set to “unknown”)
D81PTOF3STOp$general	81-3 O/F Trip

D81PTOF4

This section defines logical node data for the logical node D81PTOF4of the logical device Protection.

Data Name	Description
D81PTOF4STStr$general	81-4 O/F Trip
D81PTOF4STStr$dirGeneral	81-4 O/F Direction (set to “unknown”)
D81PTOF4STOp$general	81-4 O/F Trip

D81PTUF1

This section defines logical node data for the logical node D81PTUF1of the logical device Protection.

Data Name	Description
D81PTUF1STStr$general	81-1 U/F Trip
D81PTUF1STStr$dirGeneral	81-1 U/F Direction (set to “unknown”)
D81PTUF1STOp$general	81-1 U/F Trip

D81PTUF2

This section defines logical node data for the logical node D81PTUF2of the logical device Protection.

Data Name	Description
D81PTUF2STStr$general	81-2 U/F Trip
D81PTUF2STStr$dirGeneral	81-2 U/F Direction (set to “unknown”)
D81PTUF2STOp$general	81-2 U/F Trip

D81PTUF3

This section defines logical node data for the logical node D81PTUF3of the logical device Protection.

Data Name	Description
D81PTUF3STStr$general	81-3 U/F Trip
D81PTUF3STStr$dirGeneral	81-3 U/F Direction (set to “unknown”)
D81PTUF3STOp$general	81-3 U/F Trip

D81PTUF4

This section defines logical node data for the logical node D81PTUF4of the logical device Protection.

Data Name	Description
D81PTUF4STStr$general	81-4 U/F Trip
D81PTUF4STStr$dirGeneral	81-4 U/F Direction (set to “unknown”)
D81PTUF4STOp$general	81-4 U/F Trip

D87TPDIF1

This section defines logical node data for the logical node D87TPDIF1of the logical device Protection.

Data Name	Description
D87TPDIF1STOp$general	87 Trip
D87TPDIF1STOp$phsA	87 Trip phase A
D87TPDIF1STOp$phsB	87 Trip phase B
D87TPDIF1STOp$phsC	87 Trip phase C

D87NHVPDIF2

This section defines logical node data for the logical node D87NHVPDIF2of the logical device Protection.

Data Name	Description
D87NHVPDIF2STOp$general	87N-HV Trip

D87NLVPDIF3

This section defines logical node data for the logical node D87NLVPDIF3of the logical device Protection.

Data Name	Description
D87NLVPDIF3STOp$general	87N-LV Trip

D87NTVPDIF4

This section defines logical node data for the logical node D87NTVPDIF43of the logical device Protection.

Data Name	Description
D87NTVPDIF4STOp$general	87N-TV Trip

PTFuseGGIO1

This section defines logical node data for the logical node PTFuseGGIO1of the logical device Protection.

Data Name	Description
PTFuseGGIO1STInd$stVal	60 Alarm

EIGGIO1

This section defines logical node data for the logical node EIGGIO1of the logical device System.

Data Name	Description
EIGGIO1STInd1$stVal	External Input 1
EIGGIO1STInd2$stVal	External Input 2
EIGGIO1STInd3$stVal	External Input 3
EIGGIO1STInd4$stVal	External Input 4
EIGGIO1STInd5$stVal	External Input 5
EIGGIO1STInd6$stVal	External Input 6
EIGGIO1STInd7$stVal	External Input 7
EIGGIO1STInd8$stVal	External Input 8
EIGGIO1STInd9$stVal	External Input 9
EIGGIO1STInd10$stVal	External Input 10
EIGGIO1STInd11$stVal	External Input 11
EIGGIO1STInd12$stVal	External Input 12
EIGGIO1STInd13$stVal	External Input 13
EIGGIO1STInd14$stVal	External Input 14
EIGGIO1STInd15$stVal	External Input 15
EIGGIO1STInd16$stVal	External Input 16
EIGGIO1STInd17$stVal	External Input 17
EIGGIO1STInd18$stVal	External Input 18
EIGGIO1STInd19$stVal	External Input 19
EIGGIO1STInd20$stVal	External Input 20

OCGGIO2

This section defines logical node data for the logical node OCGGIO2of the logical device System.

Data Name	Description
OCGGIO2STInd1$stVal	Output Contact 1
OCGGIO2STInd2$stVal	Output Contact 2
OCGGIO2STInd3$stVal	Output Contact 3
OCGGIO2STInd4$stVal	Output Contact 4
OCGGIO2STInd5$stVal	Output Contact 5
OCGGIO2STInd6$stVal	Output Contact 6
OCGGIO2STInd7$stVal	Output Contact 7
OCGGIO2STInd8$stVal	Output Contact 8
OCGGIO2STInd9$stVal	Output Contact 9
OCGGIO2STInd10$stVal	Output Contact 10
OCGGIO2STInd11$stVal	Output Contact 11
OCGGIO2STInd12$stVal	Output Contact 12
OCGGIO2STInd13$stVal	Output Contact 13
OCGGIO2STInd14$stVal	Output Contact 14
OCGGIO2STInd15$stVal	Output Contact 15
OCGGIO2STInd16$stVal	Output Contact 16
OCGGIO2STInd17$stVal	Output Contact 17
OCGGIO2STInd18$stVal	Output Contact 18
OCGGIO2STInd19$stVal	Output Contact 19
OCGGIO2STInd20$stVal	Output Contact 20
OCGGIO2STInd21$stVal	Output Contact 21

PLGGIO3

This section defines logical node data for the logical node PLGGIO3of the logical device System.

Data Name	Description
PLGGIO3STInd1$stVal	ProLogic 1
PLGGIO3STInd2$stVal	ProLogic 2
PLGGIO3STInd3$stVal	ProLogic 3
PLGGIO3STInd4$stVal	ProLogic 4
PLGGIO3STInd5$stVal	ProLogic 5
PLGGIO3STInd6$stVal	ProLogic 6
PLGGIO3STInd7$stVal	ProLogic 7
PLGGIO3STInd8$stVal	ProLogic 8
PLGGIO3STInd9$stVal	ProLogic 9
PLGGIO3STInd10$stVal	ProLogic 10
PLGGIO3STInd11$stVal	ProLogic 11
PLGGIO3STInd12$stVal	ProLogic 12
PLGGIO3STInd13$stVal	ProLogic 13
PLGGIO3STInd14$stVal	ProLogic 14
PLGGIO3STInd15$stVal	ProLogic 15
PLGGIO3STInd16$stVal	ProLogic 16
PLGGIO3STInd17$stVal	ProLogic 17
PLGGIO3STInd18$stVal	ProLogic 18
PLGGIO3STInd19$stVal	ProLogic 19
PLGGIO3STInd20$stVal	ProLogic 20
PLGGIO3STInd21$stVal	ProLogic 21
PLGGIO3STInd22$stVal	ProLogic 22
PLGGIO3STInd23$stVal	ProLogic 23
PLGGIO3STInd24$stVal	ProLogic 24

XFMRGGIO4

This section defines logical node data for the logical node XFMRGGIO4of the logical device System.

Data Name	Description
XFMRGGIO4STInd1$stVal	TOEWS 15 Minutes Alarm
XFMRGGIO4STInd2$stVal	TOEWS 30 Minutes Alarm
XFMRGGIO4STInd3$stVal	TOEWS Trip
XFMRGGIO4STInd4$stVal	THD Alarm
XFMRGGIO4STInd5$stVal	Ambient Temperature Alarm
XFMRGGIO4STInd6$stVal	Top Oil Temperature Alarm
XFMRGGIO4STInd1$stVal	I*I*T Alarm

SGGGIO5

This section defines logical node data for the logical node SGGGIO5of the logical device System.

Data Name	Description
SGGGIO5STIntIn$stVal	Active Settings Group

VIGGIO6

This section defines logical node data for the logical node VIGGIO6of the logical device System.

Data Name	Description
VIGGIO6STInd1$stVal	Virtual Input 1
VIGGIO6STInd2$stVal	Virtual Input 2
VIGGIO6STInd3$stVal	Virtual Input 3
VIGGIO6STInd4$stVal	Virtual Input 4
VIGGIO6STInd5$stVal	Virtual Input 5
VIGGIO6STInd6$stVal	Virtual Input 6
VIGGIO6STInd7$stVal	Virtual Input 7
VIGGIO6STInd8$stVal	Virtual Input 8
VIGGIO6STInd9$stVal	Virtual Input 9
VIGGIO6STInd10$stVal	Virtual Input 10
VIGGIO6STInd11$stVal	Virtual Input 11
VIGGIO6STInd12$stVal	Virtual Input 12
VIGGIO6STInd13$stVal	Virtual Input 13
VIGGIO6STInd14$stVal	Virtual Input 14
VIGGIO6STInd15$stVal	Virtual Input 15
VIGGIO6STInd16$stVal	Virtual Input 16
VIGGIO6STInd17$stVal	Virtual Input 17
VIGGIO6STInd18$stVal	Virtual Input 18
VIGGIO6STInd19$stVal	Virtual Input 19
VIGGIO6STInd20$stVal	Virtual Input 20
VIGGIO6STInd21$stVal	Virtual Input 21
VIGGIO6STInd22$stVal	Virtual Input 22
VIGGIO6STInd23$stVal	Virtual Input 23
VIGGIO6STInd24$stVal	Virtual Input 24
VIGGIO6STInd25$stVal	Virtual Input 25
VIGGIO6STInd26$stVal	Virtual Input 26
VIGGIO6STInd27$stVal	Virtual Input 27
VIGGIO6STInd28$stVal	Virtual Input 28
VIGGIO6STInd29$stVal	Virtual Input 29
VIGGIO6STInd30$stVal	Virtual Input 30

LEDGGIO7

This section defines logical node data for the logical node LEDGGIO7of the logical device System.

Data Name	Description
LEDGGIO7STInd1$stVal	Target LED 1 State
LEDGGIO7STInd2$stVal	Target LED 2 State
LEDGGIO7STInd3$stVal	Target LED 3 State
LEDGGIO7STInd4$stVal	Target LED 4 State
LEDGGIO7STInd5$stVal	Target LED 5 State
LEDGGIO7STInd6$stVal	Target LED 6 State
LEDGGIO7STInd7$stVal	Target LED 7 State
LEDGGIO7STInd8$stVal	Target LED 8 State
LEDGGIO7STInd9$stVal	Target LED 9 State
LEDGGIO7STInd10$stVal	Target LED 10 State
LEDGGIO7STInd11$stVal	Target LED 11 state
LEDGGIO7STInd12$stVal	Alarm LED state
LEDGGIO7STInd13$stVal	Service Required LED state

SChAlmGGIO8

This section defines logical node data for the logical node SChAlmGGIO8of the logical device System.

Data Name	Description
SChAlmGGIO8STInd$stVal	Self Check Fail Alarm

TSAlmGGIO9

This section defines logical node data for the logical node TSAlmGGIO9of the logical device System.

Data Name	Description
TSAlmGGIO9STInd$stVal	Time Synchronization Alarm

SUBSCRGGIO1

This section defines logical node data for the logical node SUBSCRGGIO1of the logical device VirtualInputs.

Data Name	Description
SUBSCRGGIO1STInd1$stVal	Subscribed GOOSE Virtual Input 1
SUBSCRGGIO1STInd2$stVal	Subscribed GOOSE Virtual Input 2
SUBSCRGGIO1STInd3$stVal	Subscribed GOOSE Virtual Input 3
SUBSCRGGIO1STInd4$stVal	Subscribed GOOSE Virtual Input 4
SUBSCRGGIO1STInd5$stVal	Subscribed GOOSE Virtual Input 5
SUBSCRGGIO1STInd6$stVal	Subscribed GOOSE Virtual Input 6
SUBSCRGGIO1STInd7$stVal	Subscribed GOOSE Virtual Input 7
SUBSCRGGIO1STInd8$stVal	Subscribed GOOSE Virtual Input 8
SUBSCRGGIO1STInd9$stVal	Subscribed GOOSE Virtual Input 9
SUBSCRGGIO1STInd10$stVal	Subscribed GOOSE Virtual Input 10
SUBSCRGGIO1STInd11$stVal	Subscribed GOOSE Virtual Input 11
SUBSCRGGIO1STInd12$stVal	Subscribed GOOSE Virtual Input 12
SUBSCRGGIO1STInd13$stVal	Subscribed GOOSE Virtual Input 13
SUBSCRGGIO1STInd14$stVal	Subscribed GOOSE Virtual Input 14
SUBSCRGGIO1STInd15$stVal	Subscribed GOOSE Virtual Input 15
SUBSCRGGIO1STInd16$stVal	Subscribed GOOSE Virtual Input 16
SUBSCRGGIO1STInd17$stVal	Subscribed GOOSE Virtual Input 17
SUBSCRGGIO1STInd18$stVal	Subscribed GOOSE Virtual Input 18
SUBSCRGGIO1STInd19$stVal	Subscribed GOOSE Virtual Input 19
SUBSCRGGIO1STInd20$stVal	Subscribed GOOSE Virtual Input 20
SUBSCRGGIO1STInd21$stVal	Subscribed GOOSE Virtual Input 21
SUBSCRGGIO1STInd22$stVal	Subscribed GOOSE Virtual Input 22
SUBSCRGGIO1STInd23$stVal	Subscribed GOOSE Virtual Input 23
SUBSCRGGIO1STInd24$stVal	Subscribed GOOSE Virtual Input 24
SUBSCRGGIO1STInd25$stVal	Subscribed GOOSE Virtual Input 25
SUBSCRGGIO1STInd26$stVal	Subscribed GOOSE Virtual Input26
SUBSCRGGIO1STInd27$stVal	Subscribed GOOSE Virtual Input 27
SUBSCRGGIO1STInd28$stVal	Subscribed GOOSE Virtual Input 28
SUBSCRGGIO1STInd29$stVal	Subscribed GOOSE Virtual Input 29
SUBSCRGGIO1STInd30$stVal	Subscribed GOOSE Virtual Input 30

D87NHVMMXN1

This section defines logical node data for the logical node D87NHVMMXN1 of the logical device FaultData

Data Name	Description
D87NHVMMXN1MXAmp1magf	87N-HV fault operating current magnitude
D87NHVMMXN1MXAmp2magf	87N-HV fault restraint current magnitude

D87NLVMMXN2

This section defines logical node data for the logical node D87NLVMMXN2 of the logical device FaultData

Data Name	Description
D87NLVMMXN2MXAmp1magf	87N-LV fault operating current magnitude
D87NLVMMXN2MXAmp2magf	87N-LV fault restraint current magnitude

D87NTVMMXN3

This section defines logical node data for the logical node D87NTVMMXN3 of the logical device FaultData

Data Name	Description
D87NTVMMXN3MXAmp1magf	87N-TV fault operating current magnitude
D87NTVMMXN3MXAmp2magf	87N-TV fault restraint current magnitude

D24DEFMMXU1

This section defines logical node data for the logical node D24DEFMMXU1of the logical device FaultData.

Data Name	Description
D24DEFMMXU1MXHzmagf	24DEF-1 fault frequency

D24DEFMMXU2

This section defines logical node data for the logical node D24DEFMMXU2 of the logical device FaultData.

Data Name	Description
D24DEFMMXU2MXHzmagf	24DEF-2 fault frequency

D24InvMMXU3

This section defines logical node data for the logical node D24InvMMXU3of the logical device FaultData.

Data Name	Description
D24InvMMXU3MXHzmagf	24INV fault frequency

D50NHVMMXU4

This section defines logical node data for the logical node D50NHVMMXU4of the logical device FaultData.

Data Name	Description
D50NHVMMXU4MXA$phsA$cValmagf	50N-HV phase A fault current magnitude
D50NHVMMXU4MXA$phsA$cValangf	50N-HV phase A fault current angle

D51NHVMMXU5

This section defines logical node data for the logical node D51NHVMMXU5of the logical device FaultData.

Data Name	Description
D51NHVMMXU5MXA$phsA$cValmagf	51N-HV phase A fault current magnitude
D51NHVMMXU5MXA$phsA$cValangf	51N-HV phase A fault current angle

D50NLVMMXU6

This section defines logical node data for the logical node D50NLVMMXU6of the logical device FaultData.

Data Name	Description
D50NLVMMXU6MXA$phsB$cValmagf	50N-LV phase B fault current magnitude
D50NLVMMXU6MXA$phsB$cValangf	50N-LV phase B fault current angle

D51NLVMMXU7

This section defines logical node data for the logical node D51NLVMMXU7of the logical device FaultData.

Data Name	Description
D51NLVMMXU7MXA$phsB$cValmagf	51N-LV phase B fault current magnitude
D51NLVMMXU7MXA$phsB$cValangf	51N-LV phase B fault current angle

D50NTVMMXU8

This section defines logical node data for the logical node D50NTVMMXU8of the logical device FaultData.

Data Name	Description
D50NTVMMXU8MXA$phsC$cValmagf	50N-TV phase C fault current magnitude
D50NTVMMXU8MXA$phsC$cValangf	50N-TV phase C fault current angle

D51NTVMMXU9

This section defines logical node data for the logical node D51NTVMMXU9of the logical device FaultData.

Data Name	Description
D51NTVMMXU9MXA$phsC$cValmagf	51N-TV phase C fault current magnitude
D51NTVMMXU9MXA$phsC$cValangf	51N-TV phase C fault current angle

D50HVMMXU10

This section defines logical node data for the logical node D50HVMMXU10of the logical device FaultData.

Data Name	Description
D50HVMMXU10MXA$phsA$cValmagf	50-HV phase A fault current magnitude
D50HVMMXU10MXA$phsA$cValangf	50-HV phase A fault current angle
D50HVMMXU10MXA$phsB$cValmagf	50-HV phase B fault current magnitude
D50HVMMXU10MXA$phsB$cValangf	50-HV phase B fault current angle
D50HVMMXU10MXA$phsC$cValmagf	50-HV phase C fault current magnitude
D50HVMMXU10MXA$phsC$cValangf	50-HV phase C fault current angle

D51HVMMXU11

This section defines logical node data for the logical node D51HVMMXU11of the logical device FaultData.

Data Name	Description
D51HVMMXU11MXA$phsA$cValmagf	51-HV phase A fault current magnitude
D51HVMMXU11MXA$phsA$cValangf	51-HV phase A fault current angle
D51HVMMXU11MXA$phsB$cValmagf	51-HV phase B fault current magnitude
D51HVMMXU11MXA$phsB$cValangf	51-HV phase B fault current angle
D51HVMMXU11MXA$phsC$cValmagf	51-HV phase C fault current magnitude
D51HVMMXU11MXA$phsC$cValangf	51-HV phase C fault current angle

D50LVMMXU12

This section defines logical node data for the logical node D50LVMMXU12of the logical device FaultData.

Data Name	Description
D50LVMMXU12MXA$phsA$cValmagf	50-LV phase A fault current magnitude
D50LVMMXU12MXA$phsA$cValangf	50-LV phase A fault current angle
D50LVMMXU12MXA$phsB$cValmagf	50-LV phase B fault current magnitude
D50LVMMXU12MXA$phsB$cValangf	50-LV phase B faul tcurrent angle
D50LVMMXU12MXA$phsC$cValmagf	50-LV phase C fault current magnitude
D50LVMMXU12MXA$phsC$cValangf	50-LV phase C fault current angle

D51LVMMXU13

This section defines logical node data for the logical node D51LVMMXU13of the logical device FaultData.

Data Name	Description
D51LVMMXU13MXA$phsA$cValmagf	51-LV phase A fault current magnitude
D51LVMMXU13MXA$phsA$cValangf	51-LV phase A fault current angle
D51LVMMXU13MXA$phsB$cValmagf	51-LV phase B fault current magnitude
D51LVMMXU13MXA$phsB$cValangf	51-LV phase B fault current angle
D51LVMMXU13MXA$phsC$cValmagf	51-LV phase C fault current magnitude
D51LVMMXU13MXA$phsC$cValangf	51-LV phase C fault current angle

D50TVMMXU14

This section defines logical node data for the logical node D50TVMMXU14of the logical device FaultData.

Data Name	Description
D50TVMMXU14MXA$phsA$cValmagf	50-TV phase A fault current magnitude
D50TVMMXU14MXA$phsA$cValangf	50-TV phase A fault current angle
D50TVMMXU14MXA$phsB$cValmagf	50-TV phase B fault current magnitude
D50TVMMXU14MXA$phsB$cValangf	50-TV phase B fault current angle
D50TVMMXU14MXA$phsC$cValmagf	50-TV phase C fault current magnitude
D50TVMMXU14MXA$phsC$cValangf	50-TV phase C fault current angle

D51TVMMXU15

This section defines logical node data for the logical node D51TVMMXU15of the logical device FaultData.

Data Name	Description
D51TVMMXU15MXA$phsA$cValmagf	51-TV phase A fault current magnitude
D51TVMMXU15MXA$phsA$cValangf	51-TV phase A fault current angle
D51TVMMXU15MXA$phsB$cValmagf	51-TV phase B fault current magnitude
D51TVMMXU15MXA$phsB$cValangf	51-TV phase B fault current angle
D51TVMMXU15MXA$phsC$cValmagf	51-TV phase C fault current magnitude
D51TVMMXU15MXA$phsC$cValangf	51-TV phase C fault current angle

D59_1MMXU16

This section defines logical node data for the logical node D59_1MMXU16of the logical device FaultData.

Data Name	Description
D59_1MMXU16MXPhV$phsA$cValmagf	59-1 phase A fault voltage magnitude
D59_1MMXU16MXPhV$phsA$cValangf	59-1 phase A fault voltage angle
D59_1MMXU16MXPhV$phsB$cValmagf	59-1 phase B fault voltage magnitude
D59_1MMXU16MXPhV$phsB$cValmagf	59-1 phase B fault voltage angle
D59_1MMXU16MXPhV$phsC$cValmagf	59-1 phase C fault voltage magnitude
D59_1MMXU16MXPhV$phsC$cValangf	59-1 phase C fault voltage angle

D59_2MMXU17

This section defines logical node data for the logical node D59_2MMXU17of the logical device FaultData.

Data Name	Description
D59_2MMXU17MXPhV$phsA$cValmagf	59-2 phase A fault voltage magnitude
D59_2MMXU17MXPhV$phsA$cValangf	59-2 phase A fault voltage angle
D59_2MMXU17MXPhV$phsB$cValmagf	59-2 phase B fault voltage magnitude
D59_2MMXU17MXPhV$phsB$cValangf	59-2 phase B fault voltage angle
D59_2MMXU17MXPhV$phsC$cValmagf	59-2 phase C fault voltage magnitude
D59_2MMXU17MXPhV$phsC$cValangf	59-2 phase C fault voltage angle

D27_1MMXU18

This section defines logical node data for the logical node D27_1MMXU18of the logical device FaultData.

Data Name	Description
D27_1MMXU18MXPhV$phsA$cValmagf	27-1 phase A fault voltage magnitude
D27_1MMXU18MXPhV$phsA$cValangf	27-1 phase A fault voltage angle
D27_1MMXU18MXPhV$phsB$cValmagf	27-1 phase B fault voltage magnitude
D27_1MMXU18MXPhV$phsB$cValangf	27-1 phase B fault voltage angle
D27_1MMXU18MXPhV$phsC$cValmagf	27-1 phase C fault voltage magnitude
D27_1MMXU18MXPhV$phsC$cValangf	27-1 phase C fault voltage angle

D27_2MMXU19

This section defines logical node data for the logical node D27_2MMXU19of the logical device FaultData.

Data Name	Description
D27_2MMXU19MXPhV$phsA$cValmagf	27-2 phase A fault voltage magnitude
D27_2MMXU19MXPhV$phsA$cValangf	27-2 phase A fault voltage angle
D27_2MMXU19MXPhV$phsB$cValmagf	27-2 phase B fault voltage magnitude
D27_2MMXU19MXPhV$phsB$cValangf	27-2 phase B fault voltage angle
D27_2MMXU19MXPhV$phsC$cValmagf	27-2 phase C fault voltage magnitude
D27_2MMXU19MXPhV$phsC$cValangf	27-2 phase C fault voltage angle

D67MMXU20

This section defines logical node data for the logical node D67MMXU20of the logical device FaultData.

Data Name	Description
D67MMXU20MXPhV$phsA$cValmagf	67 phase A fault voltage magnitude
D67MMXU20MXPhV$phsA$cValangf	67 phase A fault voltage angle
D67MMXU20MXPhV$phsB$cValmagf	67 phase B fault voltage magnitude
D67MMXU20MXPhV$phsB$cValangf	67 phase B fault voltage angle
D67MMXU20MXPhV$phsC$cValmagf	67 phase C fault voltage magnitude
D67MMXU20MXPhV$phsC$cValangf	67 phase C fault voltage angle
D67MMXU20MXA$phsA$cValmagf	67 phase A fault current magnitude
D67MMXU20MXA$phsA$cValangf	67 phase A fault current angle
D67MMXU20MXA$phsB$cValmagf	67 phase B fault current magnitude
D67MMXU20MXA$phsB$cValangf	67 phase B fault current angle
D67MMXU20MXA$phsC$cValmagf	67 phase C fault current magnitude
D67MMXU20MXA$phsC$cValangf	67 phase C fault current angle

D87MMXU21

This section defines logical node data for the logical node D87MMXU21of the logical device FaultData.

Data Name	Description
D87MMXU21MXA1$phsA$cValmagf	87 phase A fault operating current magnitude
D87MMXU21MXA1$phsB$cValmagf	87 phase B fault operating current magnitude
D87MMXU21MXA1$phsC$cValmagf	87 phase C fault operating current magnitude
D87MMXU21MXA2$phsA$cValmagf	87 phase A fault restraint current magnitude
D87MMXU21MXA2$phsB$cValmagf	87 phase B fault restraint current magnitude
D87MMXU21MXA2$phsC$cValmagf	87 phase C fault restraint current magnitude

D67NMMXU22

This section defines logical node data for the logical node D67NMMXU22of the logical device FaultData.

Data Name	Description
D67NMMXU22MXPhV$phsA$cValmagf	67N phase A fault voltage magnitude
D67NMMXU22MXPhV$phsA$cValangf	67N phase A fault voltage angle
D67NMMXU22MXPhV$phsB$cValmagf	67N phase B fault voltage magnitude
D67NMMXU22MXPhV$phsB$cValangf	67N phase B fault voltage angle
D67NMMXU22MXPhV$phsC$cValmagf	67N phase C fault voltage magnitude
D67NMMXU22MXPhV$phsC$cValangf	67N phase C fault voltage angle
D67NMMXU22MXA$phsA$cValmagf	67N phase A fault current magnitude
D67NMMXU22MXA$phsA$cValangf	67N phase A fault current angle
D67NMMXU22MXA$phsB$cValmagf	67N phase B fault current magnitude
D67NMMXU22MXA$phsB$cValangf	67N phase B fault current angle
D67NMMXU22MXA$phsC$cValmagf	67N phase C fault current magnitude
D67NMMXU22MXA$phsC$cValmagf	67N phase C fault current angle

D24DEFMSQI1

This section defines logical node data for the logical node D24DEFMSQI1of the logical device FaultData.

Data Name	Description
D24DEFMSQI1MXSeqV$c1$cValmagf	24DEF-1 fault positive sequence voltage magnitude
D24DEFMSQI1MXSeqV$c1$cValangf	24DEF-1 fault positive sequence voltage angle

D24DEFMSQI2

This section defines logical node data for the logical node D24DEFMSQI2 of the logical device FaultData.

Data Name	Description
D24DEFMSQI2MXSeqV$c1$cValmagf	24DEF-2 fault positive sequence voltage magnitude
D24DEFMSQI2MXSeqV$c1$cValangf	24DEF-2 fault positive sequence voltage angle

D24InvMSQI3

This section defines logical node data for the logical node D24InvMSQI3of the logical device FaultData.

Data Name	Description
D24InvMSQI3MXSeqV$c1$cValmagf	24INV fault positive sequence voltage magnitude
D24InvMSQI3MXSeqV$c1$cValangf	24INV fault positive sequence voltage angle

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